EVALUATION OF PERFORMANCE OF SELECTED FODDER GRASSES AS ALTERNATIVE TO NAPIER *(PENNISETUM PURPUREUM SCHUMACH)* IN WESTERN KENYA

BY

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DECLARATIONS

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DEDICATION

This thesis is dedicated to my wife Alice N. Munyasi, my daughter Faith Nanyama, and my sons Peter Situma, Sam Wafula and Seth Simiyu.

ABSTRACT

Napier grass (*Pennisetum purpureum* Schumach), the most preferred fodder species for dairy production in East and Central Africa, is under threat from stunt disease that can reduce forage yield by 40 to 90%. Field trials were conducted at KALRO Kakamega (high rainfall) and Alupe (medium rainfall) to evaluate selected fodder grasses, Guinea grass *(Panicum maximum* Jacq*)* and Guatemala grass *(Tripsacum laxum* Scrib and Merr*)* and a new stunt disease tolerant Napier *cv Ouma* 3 on biomass production potential and morphological characteristics in relation to defoliation density (5, 10 and 15 cm) and frequency of harvest (4, 8 and 12 weeks). A Randomized Complete Block Design (RCBD) laid in a split-split plot was used. The influence of 4-weekly intervals of harvest alongside defoliation height of 10 cm on Napier *cv Ouma* yielded the highest dry matter (38.5t/ha/year and 35 t/ha/year) at Kakamega and Alupe sites respectively. Among the alternative fodder, *Panicum maximum* yielded the highest dry matter (27 t/ha/year and 25.4 t/ha/year) at Kakamega and Alupe sites respectively when harvested at 4-weekly interval alongside defoliation height of 10cm. Morphological characteristics significantly varied between interaction of species, frequency of harvest and defoliation height at both study sites. Nutrient and mineral concentration in the harvested forages differed significantly between the species with *Tripsacum laxum* containing the highest crude protein levels (8.9% to 9.2%) at both study sites, though the Acid Detergent Fibre (ADF) level was lower than in Napier *cv Ouma* and *Panicum maximum* regardless of frequency of harvest and defoliation height. The leaf part showed the highest concentration of CP than the stem part regardless of the species, frequency of harvest and defoliation height. The fibre content was higher in stem than in leaf part. The effect of three irrigation intervals (2, 4 and 6 days) and two fertilizer level (recommended rate of 100kg/ha of DAP and control) on morphological characteristics of selected alternative fodder grasses was examined in the greenhouse to determine their effect on fodder growth and deveopment. A RCBD with factorial arrangement was applied. Irrigation intervals of two days alongside fertilize application performed significantly better than the four and six days. Therefore farmers in western Kenya should apply fertilizer at recommended rate and irrigated at either two or four days interval to attain optimum fodder growth growing fodder. It is recommended that farmers in western Kenya should plant *Panicum maximum* as high yielding forage and *Tripsacum laxum* for high quality and should be harvested at 4-weekly interval alongside defoliation height of 10 cm.

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ACRONYMS

ADF	Acid Detergent Fibre
ANOVA	Analysis of Variance
asl	Above Sea Level
CAN	Calcium Ammonium Nitrate
DAP	Di-ammonium phosphate
DMRT	Duncan Multiple Range Test
DP	Digestible Protein
FAO	Food and Agriculture Organization of the United Nation
KARLO	Kenya Agricultural and Livestock Research organization
LM	Lower Midlands
LR	Long Rains
NGO	Non-Governmental Organization
NSD	Napier Stunt Disease
SR	Short Rains
TDN	Total Digestible Nutrients
WAP	Week After Planting

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CHAPTER ONE

INTRODUCTION

1.1 Background

Forage play pivotal role in the agricultural economy of developing countries by providing the cheapest source of feed for livestock. However, in Sub-Saharan Africa and East Africa in particular, livestock farmers experience inadequate forage supply to dairy animals and other livestock species due to overdependence on Napier grass and crop residues which are now under threat from Napier Stunt Disease (NSD) and Napier Head Smut Disease (NHSD). In addition, the land sub-division has also contributed to feed shortage through limited available land for pasture establishment (Jones *et al.,* 2004, Muia *et al.*, 1999). The two diseases have the potential of reducing forage yield by 40% to 90% (ILRI, 2013, Mulaa *et al.,* 2004). However, no other high yielding alternative fodder species have been identified to replace or complement Napier grass in the smallholder farms of Western Kenya (Pleasantville, 2010).

The selection and management process of fodder grass for dairy animals involves assessment of morphological factors, dry matter yield and quality characteristics. It is however, the responsibility of livestock keepers to maintain an adequate herbage yield and quality throughout the growing season (Mohajer *et al*., 2013). In addition, forage yield is influenced by types of forage species grown, frequency of harvest and defoliation height (Byrne *et al*., 2011, Hoglind *et al*., 2005). Defoliation of forage is about removal of plant shoots which carry the leaves and therefore, favorable leaf replacement on a given plant after defoliation could be attained by scheduling appropriate interval of harvest alongside basal defoliation height to promote new tiller and leaf formation (Ball *et al.,* 2001). The response of forage species to defoliation has been emphasized because of the extensive use of pastureland as a source of forage for both domestic livestock and wildlife. This concern has led to incorporation of defoliation intensities and frequencies of harvest to various grazing systems and prescribed for effective management in order to minimize detrimental consequences of over-grazing (Briske and Richards, 1995). In the IV International Grassland Congress, Humphreys, (1997) reported that defoliation height and frequency of harvest are key factors for improving pastures. Dahl and Hyder, (1977) related plant vigor, productivity and carbohydrate reserves on frequency of harvest, defoliation height and season of defoliation. It therefore implies that under natural grazing system, timely interval of grazing alongside defoliation heights may influence strong tillering ability, biomass yield and improved forage quality for subsequent grazing.

Livestock feeds and their nutritive value determine the productivity of grazing land (Government of Kenya, 2009). Vallentine, (1990) reported that nutrient balance for livestock depends on basic factors such as animal's nutrient requirements and nutrient contents, digestibility and amount of feeds consumed. The performance of dairy animals depend on the consistent availability of quality forage in adequate amount (Sarwar *et al*., 2002). Among the many options to overcome the shortage of quality forage is the introduction of high yielding forage variety that is tolerant to frequent harvests (Bilal and Lateef., 2001).

The sources of livestock feeds in Kenya include roughage, concentrates, minerals and vitamins, which account for up to 80 percent of production costs of farm animals (Government of Kenya, 2009). In low-rainfall areas where extensive livestock production is practiced, minimal supplementation with concentrates and minerals exist compared to high-rainfall areas (Mnene, 2006). In areas where concentrates make a significant proportion of livestock diet, the cost of forage production is higher than in the low-rainfall areas where minimal inputs are used (Government of Kenya, 2009). Therefore, understanding the nutrient content of the available alternative forages and a newly developed Napier *cv Ouma* will reduce costs on commercial feed supplements and also increase milk production for dairy farmers in Western Kenya.

1.2 Statement of the Problem

The main problem of forage production in Western Kenya is Stunt disease that has affected Napier grass, which is the main fodder crop that dairy farmers rely on for feeding their animals (Wamalwa, 2013, Lusweti et al., 2004). The smallholder dairy farmers are therefore in need of an alternative fodder grass to Napier with high yield and tolerant to environmental stresses such as more frequent harvest and intense basal defoliation height, drought, diseases and nutrient deficiency among others. Emerging evidence now show that there are alternative fodders within Western Kenya which could be used by livestock keepers to overcome feed shortage in the region (KARI Kitale, 2005). However, insufficient information exists on the appropriate basal defoliation height, frequency of harvest with regard to morphological characteristics, biomass yield and quality levels. Through this study, selected alternative fodder grasses to Napier grass were evaluated for biomass yield, morphological characteristics and quality in relation to appropriate frequency of harvest and defoliation height so as to identify the most potential species for dairy farmers in Western Kenya and other areas with similar ecological conditions. Nutrient depletion from the soil as a result of frequent harvest of forage is experienced in most pasture farms in western. Therefore detail evaluation of alternative grasses to soil nutrient as well as moisture requirements. The selected alternative grasses were: Guinea grass *(Panicum maximum* Jacq*)*, *Guatemala* grass *(Tripsacum laxum*Scrib and Merr*)* and the Napier grass was Napier *cv Ouma*(*Pennisetum purpureum* Schumach).

1.3 Justification

The threat of NSD on Napier grass has provoked researchers and livestock farmers to explore alternative high yielding fodder grasses to Napier grass in order to keep and maintain dairy production in Kenya (Taruss, 2010). Some potential alternative fodder species to Napier grass were suggested by Lusweti *et al*., (2004) but their quantitative and qualitative assessment in relation to frequency of harvest alongside defoliation heights has not been fully investigated at both on-farm and green house under controlled environment. Potential alternative grasses are several including Guinea grass (*Panicum maximum*) and Guatemala grass (*Tripsacum laxum*) which were selected and compared with Napier *cv Ouma*. Napier *cv Ouma* was selected because of its tolerance to Stunt disease in western Kenya *(*Wamalwa, 2013). However, scanty information on this Napier grass variety exists in relation to potential yield and nutrient content resulting from different frequencies of harvest alongside defoliation heights as well as their response to moisture and fertilizer stress. Information on the frequency of harvesting and defoliation height will assist dairy farmers to maximize on yield when harvested at appropriate stage and sustain growth. Analytical studies of forage content are most useful when formulating feeds for livestock especially the lactating dairy cows and young growing livestock (FAO, 2004). Knowing nutrient content of alternative fodder grasses in the current study will allow dairy farmers to quantify nutrient supplements for their animals. This is because considerable variation exists in nutrient concentration between fodder species and ecological conditions similar to Western Kenya as well as phenological stages (Saddul *et al.,* 2004) hence the need for this study in the field and green house. Through this investigation, environmental factors which influence dry matter yield as well as nutrient content in the selected alternative fodder grasses will be isolated and recommended to dairy farmers in Western Kenya, with a view to increasing milk production and income for their livelihood.

1.4 Broad objective

The broad objective of the study was to identify and evaluate selected alternative forage species to Napier *cv Ouma* with optimal quality and quantity of yield in relation to the prevailing environmental and physiological stresses in Western Kenya.

1.4.1 Specific objectives

1. To evaluate the effect of frequency of harvest alongside basal defoliation height on biomass yield and morphological characteristics of alternative fodder grasses (*Panicum maximum* and *Tripsacum laxum*) and Napier grass *cv Ouma* in Western Kenya

2. To determine the effects of frequency of harvest alongside defoliation height on nutrient content of alternative fodder grasses (*Panicum maximum* and *Tripsacum laxum*) and Napier grass *cv Ouma* in Western Kenya

3. To monitor the influence of watering frequency and fertilizer levels on growth and development of alternative fodder grasses (Panicum maximum and Tripsacum laxum) and Napier grass cv Ouma

1.5 Research Hypothesis

1. A comparable alternative fodder species to Napier grass *cv Ouma* exist in dry matter yield resulting from the influence of frequency of harvest alongside defoliation height.

2. Frequency of harvest alongside basal defoliation height influence biomass yield, morphological characteristics and nutrient content of alternative fodder grass to Napier grass *cv Ouma*.

3. Soil moisture and fertility levels influence growth and development of alternative fodder grasses to Napier *cv Ouma*.

1.6 Scope and limitation of the study

The study was conducted in Western Kenya that occupies a surface area of 8,361 km^2 with a total population of 4,334,202 inhabitants (Government of Kenya 2009).Western Kenya has diverse physical features, from the hills of northern Bungoma County to the plains bordering Lake Victoria in Busia County. The highest point in the region is the peak of Mount Elgon, while the lowest point is the town of Busia. The present study site had two ecological zones (LM 2 and LM 3) leading to restricted applicability of the results in other areas of Western Kenya. The study focused on two selected potential alternative fodder grasses and compared them with a newly identified Napier *cv Ouma* that is tolerant to Stunt disease out of the many alternative fodder grasses and Napier grass available in Western Kenya (Orodho, 2006). The investigation in the study focused mainly on the influence of frequency of harvest alongside basal defoliation heights on dry matter yield, morphological characteristics and nutrient content in the field. The field study was carried out in four seasons (2 years), the time which was sufficient enough to develop some trend on the treatment effects. Detailed study on the same species was conducted in the green house to evaluate morphological characteristics under varying moisture regimes and fertilizer levels. The greenhouse trials were observed for 15 weeks.

CHAPTER TWO

LITERATURE REVIEW

2.1 Historical background of pasture work in Kenya

Eastern Africa is recognized as the center of origin and distribution of most economically important tropical and sub-tropical forage species, which contribute to about 20% – 25% of the total sown pasture species in the world (Bogdan, 1977). Indigenous grasses found in East Africa are outstanding in yield, having demonstrated their wide adaptation in many other sub-tropical countries under different ecological conditions. The pioneering work on pasture research in Kenya started in 1927 by a botanical survey which classified the country into eight regions based on natural vegetation types (Bogdan, 1977). The high rainfall areas were recommended for intensive farming with suitable pasture species while the low rainfall regions were recommended for extensive farming and rangeland management. Since 1951, rapid progress on forage collection has been made with introduction of new varieties of pasture grasses and legumes (Orodho, 2006). This offered a starting point for selecting several species and better varieties for extension and research purposes. For example, Elmba Rhodes was selected from Mbarara rhodes and Boma rhodes was selected from Masaba Rhodes. Nasiwa setaria was selected from Nandi setaria and *Pennisetum purpureum*, Clone 13 was selected from French Cameroon accessions (Orodho, 2006).

During the Kenya/FAO project on forage collection and evaluation (1974–1987), a total of 202 grass accessions were collected from various parts of the country (FAO, 2004). Some of the grass species collected were *Panicum maximum*, *Cenchrus ciliaris*, *Chloris* *gayana, Digitaria milanjiana, Enteropogon macrostachyus, Cynodon dactylon, Eragrostis superba, Leptochloa obtusifolia* and *Setaria sphacelata*. The project also re-introduced promising exotic forage crops which had originally been taken away from Kenya and improved elsewhere for superior types. These forage materials were tested and evaluated in various agro-ecological zones of Kenya and the promising ones were recommended for growing in those regions (Orodho, 2006). However, scanty information exist on these species with regard to dry matter yield and nutrient content in relation to frequency of harvest alongside defoliation heights as well as their response to moisture and fertilizer stresses.

2.2 Dairy production in Kenya

In Kenya, dairy industry accounts for 4.1% of Gross Domestic Product (GDP) with small holder dairy production accounting for over 70% of the total milk produced (Government of Kenya 2008). The population of dairy cattle is about 3.8 million (Government of Kenya, 2008). A survey conducted by Smallholder Dairy Project (SDP) reported a population of 6.7 million dairy cattle in Kenya (SDP, 2005) while the Food Agricultural Organization (FAO) estimated a population of 5.5 million milking animals (Techno-serve, 2008). The accuracy of dairy cattle population in Kenya seems to depend on the sampling methods used and the willingness of livestock keepers giving correct information. However, synthesis of the figures provided above, it can be estimated to range from 4 million to 6 million. As a sub-sector in agriculture, dairy industry is one of the most vibrant enterprises in East Africa and has the highest milk production per capita and consumption (Muriuki *et al*., 2004). Apart from South Africa, Kenya is the only country in Africa that produces enough milk for both domestic consumption and export market (Wambugu *et al*., 2011). Kenyans especially from Western Kenya are amongst the highest milk consumers in the developing world, consuming an estimated 145 litres per person per year, more than five times milk consumption in other East African countries (SDP, 2005).

Dairy production in Kenya is divided into small scale and large scale. The small scale farming is the most popular as it constitutes 70% - 80% of the total dairy subsector (IFAD, 2006). The smallholder group is further divided into four sub-groups which are resource poor, small scale intensive, semi intensive and crop oriented dairy farmers (IFAD, 2006). The dairy production systems in Kenya are influenced by the agro-ecological characteristics, land productivity potential and prevalence of animal diseases (IFAD, 2006). Most dairy farmers in Kenya are found in intensive the grazing system, which is also known as zero grazing. This system is commonly practiced in areas of small land sizes and urban areas where farmers feed their animals in stalls with very minimal movement (Muriuki *et al.,* 2004). Dairy production is also practiced in semi intensive system but the difference with intensive system is that the animals are allowed to graze on their own (Bebe *et al.,* 2003). The milk yield for semi intensive system is lower than intensive system. This is attributed to the use of low quality feeds and no concentrates applied (Karanja, 2003).

Although Kenya's dairy sector is contributing significantly to the national economy, household incomes and food security, the industry faces a number of technical, economic and institutional problems in milk production, processing and marketing (Karanja, 2003).

Specifically, some of the main constraints include seasonality in milk production, inadequate quantity and quality of feeds (Muriuki *et al*., 2004). Poor access to breeding, animal health and credit services and high cost of artificial insemination (AI) service are other constraining factors. In some areas, dairy producers are faced with the problem of poor infrastructure (roads, electricity), inadequate milk collection and marketing system, poor interaction and priority setting between research, extension and training, and limited farmers' involvement in the output market, hence reducing the incentives to increase milk production (SDP, 2005). Kenya Agricultural and Livestock Organization having a regional research institute in Western Kenya has tried various feed technologies to enable farmers enhance dairy production (Dairy Centre of Excellence, 2012). However, these technologies have not been tested on farm in most areas of Western Kenya besides implementing the farmer demand driven research, to enable farmers make informed decisions on any dairy technologies of interest (Kenya Agricultural Research Institute, 2009). This led to projects and institutions making blanket recommendations to farmers on dairy technologies to be adopted, including fodder grasses, hence the need for this current study.

2.3 Stunt and Smut diseases on Napier Grass (Elephant grass)

Napier grass (*Pennisetum purpureum* Schumach) is currently the most preferred fodder species for dairy production in Western Kenya. However, it is under threat from Stunt disease caused by *Candidatus* Phytoplasma oryzae (Ns-phytoplasma) belonging to the 16SrXI group, vectored by a leaf hopper *Maiestas banda* (Khan *et al.*,2006). The disease has spread rapidly with high economic loss to farmers and has been confirmed in over

90% of Napier grass fields in Kenya (Orodho, 2006, Mulaa *et al.,* 2004). The disease retards the growth of the plant and curls the leaves, progressively turning them yellow and drying them out (Khan *et al*., 2006). The effect of the disease includes reducing herbage yield by more than half, creating a feeding gap that not only hurts dairy farmers but also compromises on the quality and quantity of milk and meat products (Wamalwa, 2013). The first sighting of this infection was in Uganda's Masaka District whereby, many fields since then have been wiped out. Napier grass Head Smut is a fungal disease caused by *Ustilago kamerunensis* (Mwendia *et al.*, 2006, Khan *et al*., 2006). It is a serious problem in Central and Eastern Kenya (Khan *et al*., 2006), which has also been reported in Tanzania, Uganda, Rwanda and Congo (Khan *et al.*, 2006). The disease results in decreased biomass yield in the range of 75%-90% in Kiambu and 25%-90% in Thika, with high costs of management and milk loss of 30%-75% (Nyanyu, 1998). This signals the need to develop other alternative Napier grass cultivars and promote existing grasses which have not shown symptoms of the diseases.

2.4 Description of selected fodder grass in Western Kenya used in the study

2.4.1 Napier grass (*Pennisetum purpureum* Schum)

Napier grass is a tall, stout, deep-rooted and high-yielding perennial grass used as forage for dairy animals (Zewdu *et al.*, 2003). It is also known as Elephant grass and is widespread in East Africa, growing from sea level to 2000 m where the rainfall exceeds 1000 mm and it can withstand considerable periods of drought (Butt *et al.*, 1993). Since seeds are not viable, Napier grass is propagated from stem cuttings of three nodes, or by division of rootstocks or shoot tips (Orodho, 2006). It can provide a continual supply of green forage throughout the year and it fits in intensive small-scale farming. It is the dominant grass in zero-grazing systems and can out-yield many other grasses such as Guinea grass (*Panicum maximum*) and Rhodes grass (*Chloris gayana*) (Orodho, 2006). It can withstand repeated cutting, and four to six cuts is able to yield 50-150 tons per hectare per year (Orodho, 2006). It is the main feed for dairy cows supplemented by crop residues (ICRAF, 1997). One of the current constraints to Napier grass production in Central and Western Kenya is Napier grass Head Smut disease and Stunt disease respectively that reduces the Napier grass yields (Farrell, 1998). In Kenya the common cultivars that have been selected and tested over a wide range of environments are: Bana, French Cameroon, Clone 13 and Pakistan hybrid (Orodho, 2006). Although Napier grass is known to have high susceptibility to fungal snow mold disease (*Cowdria sphaenoides*) caused by *Beniowskia sphaenoides* (Boonman, 1997*)*, it has not been a major concern until recently when new diseases started emerging. However, a newly developed Napier grass *cv Ouma* has not been tested anywhere in Kenya (Dairy Centre of Excellency, 2012).

2.4.2 Guatemala grass (*Tripsacum laxum* Scrib and Merr)

Guatemala grass (*Tripsacum laxum* Scrib and Merr) is a robust, strongly rhizomatous, tufted and leafy perennial grass that can form large bunches. The stems can grow up to 3.5-4.5 m high and 1-5 cm in diameter. The plant remains leafy for a long time and stems and stems develop at a very late stage. The roots are shallow and the plant does not grow well during a long dry season. As the grass matures, the roots become stronger and store nutrients that are necessary for re-growth after cuttings (Cook *et al.*, 2005). The leaves are tall (0.4-1.2 m long x 9 cm broad), glabrous or sparsely hairy and the inflorescences are subdigitate with 3 to 8 slender, elongated racemes (up to 20 cm long) containing male and female spikelets (3-5 mm long).

Tripsacum laxum originated from Mexico and South America and has been introduced as fodder species in many tropical areas (FAO, 2004). It grows from sea level up to 180 m above sea level at temperatures ranging from 18°C to 30°C. It does better under good soil moisture but can withstand short droughts while it can neither bear water-logging nor flooding (Cook *et al.*, 2005). However, it can grow on a wide range of soil (including podsols, ultisols, oxisols, peats, acid sulfate soils and very acid coastal marine sands) and withstands low pH provided the soils are well-drained.

Tripsacum laxum is usually propagated by stem cuttings or rooted splits at the beginning of the rain season (Cook *et al.*, 2005). It can be planted with fast growing twinning or shrub legumes (Akyeampong and Dzowela ., 1996). The average DM yield is about 18-22 t/ha/year (Nivyobizi *et al*., 2010, Cook *et al.*, 2005) and has been recommended for cut and carry since most of the biomass is produced during the wet season and can also be stored as silage for dry season supply (Sarwatt *et al*., 2002). The species is relatively good in nutritional value, with a protein content of about 10% and low fibre content (average NDF < 70%). It is also low in DM (average 22%), which increases over time while the nutritive value decreases (Sarwatt *et al*., 2002). An important feature of *Tripsacum laxum* is its ability to remain leafy at a very late stage of development (Vargas-Rodriguez, 2009).

2.4.3 Guinea grass (*Panicum maximum* Jacq)

The genus *Panicum* comprises of more than 500 species, distributed throughout the world and includes both annuals and perennials. *Panicum maximum* is native to Africa though has now been naturalized worldwide (Cleide *et al*., 2010). The species grow naturally in the open grasslands, usually under shades and along riverbanks. It also prefers most soil types provided it is well-drained, moist and fertile, although some varieties are tolerant to low fertility and poor drainage (Cook *et al.*, 2005). *Panicum maximum* survives well in areas experiencing annual rainfall above 1000 mm with no more than 4-5 month dry period (Ecoport, 2009) and average annual day-temperature ranging from 19.1°C to 22.9°C. It is associated mutually with legumes such as *Centrosema pubescens*, *Leucaena leucocephala*, *Pueraria phaseloides* or *Macroptilium artropurpureum* (Cook *et al*., 2005). However, productivity of *Panicum maximum* varies with ecological zone and management practices. It can be utilized in form of hay, silage or direct grazing. However, dry matter yield of *Panicum maximum* is about 6.6 t/ha/year, with average crude protein concentration of 7% depending on the age and frequency of harvest Sebastien *et al*., (2008). *Panicum maximum* forms a loose to dense tuft, short rhizomatous erect root at the lower nodes. Leaf blades are linear narrowly lanceolate while the panicles are open, oblong or pyramidal with secondary branches well developed and flexuous. The species is robust perennials and grows at the height of 1.5-3.5 m tall, with stems to about 10 mm diameter. Leaves are glabrous hairy, 40 to100 cm long, 1 to 3.5cm wide, tapering to fine point. Panicles are 12-45 cm long and 12-25 cm wide, spikelets are 2.5 to 3 mm long and producing 700,000 to 2 million seeds/kg. *Panicum maximum* are propagated from root splits as well as seeds at the spacing of 0.5

m to 0.6 m in rows 1.25 m to 1.5 m apart, or as close as 40 cm in a triangular pattern if a faster cover is required.

2.5 Growth and development of plant fractions

Physiological responses to defoliation and subsequent re-growth potential are affected by developmental morphology of the plants (Brueland *et al.,* 2003). For example, development of leaves on established tillers is affected by agronomic management practices such as harvesting frequencies, basal defoliation height, fertilizers application, weeding, growth regulators and pesticide application (Moore and Moser, 1995). Decisions regarding the time of either grazing or cutting of forages are often made on the basis of plant development (Brueland *et al.*, 2003).The growth processes of each organ on plants depend on cell division and elongation which provide structure for plant tissue development and biomass accumulation (Taiz and Zaiger, 2002).

The effect of defoliation height and frequency on tiller initiation is difficult to generalize since it is confounded with phenological stage and seasonal progression of environmental variables (Briske and Richards 1995). The ability of the plant to tiller without removal of apical meri-stem is considered an indication of an efficient forage producer. Richards *et al.,* (1988) reported that rapid re-tillering is critical especially when defoliated plants compete with non-defoliated neighbors. Crested wheatgrass is an outstanding example of a species that tillers profusely following defoliation (Dahl, 1995, Briske and Richards, (1995).

Production of leaf tissue requires the initiation, elongation and maturation of new cells. Leaf development in grasses has been most extensively described because growth is mostly linear, which result in large increase in leaf length accompanied by relatively small increase in width and thickness. Both cell division and elongation of grasses are affected by the environmental and management factors that alter leaf elongation (Taiz and Zaiger, 2002). Thus, in defoliation, water deficits and nitrogen stress reduce cell division, cell elongation or both (Taiz and Zaiger, 2002).

2.6 Primary productivity of forage plants

Primary productivity is the amount of aboveground plant biomass or carbon accumulated over a specific period of time (Sala and Austin, 2000). The estimates from primary biomass production are used in the determination of forage availability and livestock carrying capacity (Byrne *et al*., 2011). Singh *et al.,* (1975) reviewed different methods of harvesting standing biomass to estimate aboveground net primary productivity. The simplest and most common method used is clipping of the green and current year dead material of grasses production at peak biomass. This method has been shown to produce estimates with low uncertainty and close to the true value (Lauenroth *et al.*, 2006).

2.7 Response of forage plants to defoliations

Understanding defoliation and plant growth interaction has direct application in the development of sustainable management strategies for pastureland (Sundriyal *et al.*, 1993). Forage yield is influenced by frequency of harvest, type of forage species, and defoliation height, season of harvest and type of soil (Byrne *et al*., 2011). This effect has been observed in many pot and field experiments (Byrne *et al*., 2011). Defoliation close to the surface of the ground influences plant to allocate resources to the shoot over roots leading to increased plant crown diameter (Byrne *et al*., 2011). The increase in plant crown diameter is attributed to the removal of apical dominance after high intensity of defoliation hence more tillering ability of the plant is induced (Gutman *et al.,* 2001). Defoliation also affects root growth and belowground carbohydrate reserves which is reflected in decreased root biomass (Gutman *et al.,* 2001). When root growth is reduced, the ability of plants to obtain water and nutrients is also reduced (Byrne *et al*., 2011). This observation has been found by Engel *et al*., (1998) who reported that root reduction due to defoliation affects the ability of plants transporting nutrients to the leaves hence retarded growth. Gutman *et al.,* (2001) observed that these potentially opposing effects of defoliation results in reduction of shoots and general stunted root growth. Although the effect of defoliation on growth of individual grass plants has been studied extensively, the magnitude and generality of compensatory growth responses has been under a great deal of discussion. Quantitative techniques are needed to obtain a more objective conclusion and reveal the conditions leading to different types of responses hence the attempt in the current study.

2.7.1 Stubble height and frequency of defoliation

The stubble height of defoliation is the height of the plant canopy after removal of the aboveground surface biomass, while frequency of harvest refers to the interval between harvests (Santos *et al.,* 2013). The quantity and quality of the aboveground surface net primary productivity is more often influenced by the frequency of harvest and basal defoliation heights (Hoglind *et al.,* 2005). Frequent harvest of forage at optimal defoliation height influences an increase in biomass yield due to more re-growth, tillering ability and leaf surface area than infrequent harvesting (Sainkhuu, 2006 cited in Baatar, 2008). Defoliation of fodder at higher basal stubble height leads to more yield than closer to the surface because re-growth is encouraged compared to the foliage harvested closer to the ground surface, which consequently affect the leaf formation and therefore photosynthetic and respiration surfaces (Baatar, 2008). The consequence of close harvesting of forage at ground level is demonstrated in some fodder species, which reserves carbohydrates in the lower stem. Similarly, some fodder plants use roots to reserve carbohydrate for use during dry seasons and therefore are affected severely by close ground defoliation (Taiz and zeiger, 2002). These plants rely on residual leaf area to supply energy for re-growth and therefore such species requires sizeable basal height left at the end of every harvest. However, this may have limited value if the leaves being left are old and previously shaded as they are inefficient in carrying out photosynthesis and are near death.

2.7.2 Persistence of forage production under defoliation

Persistence of a pasture plant reflects the extent to which plants are adaptable to the environment and also perenniality of the plants (Harmoney, 2007). Persistence of fodder to defoliation and other eco-physiological factors depends mainly on how the plants respond to defoliation, environmental extremes (drought or frost), insects and disease infection. Although persistence is associated with the survival of individual plants in the environment, (Harmoney, 2007) observed that there is also need to consider the yield of the plants. Defoliation prior to ear emergence of forage is undesirable because certain fodder species are intolerant to defoliation at that stage. However, farmers harvest forage stands at earlier stages of morphological development with an assumption that the foliage has better quality forage (Kunelius and Mcreae, 1986). This practice has been observed in cultivated fodder crops such as Napier grass, where farmers frequently harvest their crops at young vegetative or stems elongation stages to feed animals (Harmoney, 2007). This assumption need to be ascertained specially for the tested fodders in the current study.

2.8 Quality of forage plants

Forage quality is defined as the ability of the feeds to be consumed (feed intake), digested (digestibility) and the essential nutrients contained within the feeds and anti-quality factors (Ball *et al.,* 2001, Cameron, 2001). Forage quality is a direct reflection of the essential nutrient content available to the grazing animals (FAO, 2004) and is measured by crude protein, fibre and mineral contents (Zhang *et al.,* 2012). It is the role of livestock keepers to provide forage species that constitute essential nutrients for the health and production of livestock enterprise (Saun, 2006). This desired level of production is usually achieved through selection and growing quality forages (Waziri *et al.,* 2013).

The stage of plant maturity is one of the most important factors that determine the quality of forage (Stichler and Bade, 2002). Studies have demonstrated that mature plants contain more cell wall structural components, which characterize a particular forage species poor in nutritional content than young plant (Waziri *et al.,* 2013). There is also variation among forage species in terms of quality and production attributed to higher ratio of leaf to stem (Milic *et al*., 2011, Saddul *et al.,* 2004). For instance, the quality of legumes is higher than grasses throughout the phenological growth stages mainly because of their distinctiveness in leaves, which are more digestible than grasses (Cameron, 2001).

a) Dry matter

Dry matter is the most frequently performed analysis in the nutrition laboratory because the concentration of other nutrients is usually expressed on a dry matter basis (as a percentage of the dry matter). Dry matter content has been found to be useful in livestock industry, especially in areas that deal with high-moisture feeds such as feedlot and silage. Methods for Dry matter analysis include oven drying harvested forage at 60^0C for 48 hours (Galyean 2010***)***.

b) Acid Detergent Fibre (ADF)

Acid detergent fibre is the portion of the forage that remains on the filter after the forage sample is treated with a detergent and strong acid (Galyean, 2010). It includes the largely digestible cellulose, indigestible lignin and inorganic silica. Acid detergent fibre is important because it is negatively correlated with digestibility of forages. As the ADF increases, the forage becomes less digestible. ADF is the most commonly used indicator of forage quality.

c) Neutral Detergent Fibre (NDF)

Grasses contain substantial amounts of cell wall carbohydrates, which can be quantified by determination of NDF (Jancik *et al.,* 2008). These carbohydrates include cellulose, hemicelluloses and lignin (Roy *et al*., 2007). These components of carbohydrates are not easily digestible, and are often not desired in the feedstuff (Relling *et al*., 2001). It should however be noted that the level of NDF in the animal ratio influences the intake of dry matter and the time of rumination. The maturity of fodder species at harvest influences

NDF digestibility (Roy *et al*., 2007). Thus, as forage matures, NDF digestibility declines. However, when the forages are in vegetative stage, NDF digestibility is very high (>70%) (Milic *et al*., 2011). Explanation given to the changes is that as forage advance in maturity, it accumulates cellulose and other complex carbohydrates and these tissues become bound together by a process known as lignifications (Steaffer *et al.*, 2000). Lignin in plant cell wall is more difficult for rumen bacteria to digest than cellulose and hemicelluloses. However as maturity proceeds, leaf-stem ratio declines and as a result NDF digestibility declines because a greater portion of the NDF is associated with stem tissue.

d) Crude Protein

Protein is the building blocks for tissue muscle, bone, skin, hair, organs and milk. It is important not only for growth and milk production, but also for constant body repair and replacement of lost cells and tissue. Proteins requirements by cattle and in feeds are usually expressed as Crude Protein (CP), which is estimated as percentage of nitrogen multiplied by a constant 6.25 (Galyean, 2010). The concentration of CP in forages is high when harvested at early growth stage and stored under proper environment.

e) Total Digestible Nutrient

Total digestible nutrient (TDN) is the sum of digestible protein, carbohydrates and fat. For instance, high quality alfalfa hay may contain up to 65 per cent TDN, while poor quality hay or barley straw has around 45 per cent TDN (Milic *et al.*, 2011). The average cow requires 55 per cent TDN during mid-pregnancy, 60 per cent during late pregnancy and 65 per cent after calving (Milic *et al.*, 2011). If the cow's diet is completely made up of forage, her energy requirement must be met by the forage.

2.9 Minerals

The level of minerals in forage varies according to properties of the soil, level and type of fertilizer applied to the crop, forge species and maturity of the plant (Kronqvist, 2011). Generally, forage contains high levels of potassium and calcium but lower levels of magnesium and phosphorus (Kronqvist, 2011). Most naturally occurring mineral deficiencies in herbivores are associated with specific regions which are directly related to soil characteristics (McDowell *et al.,* 1983). Mayberry, (2005) observed that mineral deficiencies in livestock can cause loss of appetite resulting in a depressed growth rate, reduced milk production, reduced fertility and metabolic disorders and in severe cases, teeth and bone abnormalities. This implies that minerals are vital for normal growth, reproduction, health and proper functioning of the animal's body. Other functions of minerals include protection and maintenance of structural components of the body, organs and tissues, and are constituents of body fluids and tissues as electrolytes. Minerals also catalyze several enzymatic processes and hormone systems as well as maintaining acid-base balance, water balance and osmotic pressure in the blood and cerebral spinal fluids (Underwood and Suttle, 1999). Therefore, nutritional values of plants are essential in determining the productivity and health condition of animals (McDowell, 1996). Kronqvist, (2011) analyzed major minerals of concern to the livestock and found to be calcium (Ca), phosphorus (P), potassium (K) magnesium (Mg) and selenium (Se).

a) Calcium

Calcium contributes greatly in the development of bones and teeth as well as other body functions of the animal. The functions include blood clotting, muscle construction, and transmission of nerve impulses. Critical level of calcium required by a lactating cow is 0.18% on dry matter basis while growing calves ranges from 0.39% to 0.45% (Kronqvist, 2011). However, seasonal variations exist among fodder species (Kronqvist, 2011). Hypocalcaemia (milk fever), which may occur in early lactation is a calcium deficiency brought about by sudden increase in demand for calcium by lactating cow (Mayberry, 2005). Therefore it is essential that dairy farmers observe feeds which are enriched with calcium to limit deficiency in the in-calf and lactating cows.

b) Phosphorus

Phosphorus has several functions in animal body but primarily play an important role in bone formation and metabolism (Mayberry, 2005). The critical level of phosphorus for lactating cows is 0.25% on dry matter basis (NRC, 1984).

c) Magnesium

Livestock fed on forage diet low in magnesium causes grass tetany which is common among lactating cows, although any cattle can develop the disorder (Fardous *et al.*, 2010). The initial deficiency symptom in such animals is nervousness and muscular twitching around the face and ears. Magnesium oxide and magnesium sulfate are two common sources of supplemental magnesium. However, magnesium in dolomitic limestone is poorly available. Magnesium levels below 0.10% are of particular concern for growing and lactating cows. However, for finishing cattle, the critical level of Mg required is 0.2 percent. It is important for cattle to maintain magnesium levels in the body because deficiency will be reflected in the fodder can lead to a low magnesium count in the blood, which causes a condition called hypomagnesemic tetany, or grass staggers, a serious metabolic disease.

d) Potassium

Potassium levels of 0.6% on dry matter basis are considered adequate for beef cattle and this can be achieved by feeding animals on fresh forages. The concentration of potassium in plants is found to reduce with maturity of the plants and also less content is found in stems than leaves (Cameron, 2001. Potassium plays a major role in plant growth. It maintains the solutions in plant cells at ionic strengths suitable for maintaining strong plant walls and for the proper functioning of leaf pores (stomata) and plant processes such as photosynthesis, transport of sugars and enzyme activation. Potassium does not become a direct part of the plant structure but acts to regulate water balances, nutrient and sugar movement in plant tissue. Plants deficient in potassium cannot use other nutrients and water efficiently. They are less tolerant to stress caused by drought and water-logging and are more susceptible to pests and diseases.

CHAPTER THREE

EFFECT OF HARVEST FREQUENCY AND DEFOLIATION HEIGHT ON GROWTH AND YIELD OF SELECTED FODDER GRASSES.

3.1 Abstract

Forage quantity yield and morphological characteristics dependents on the frequency of harvest, basal defoliation height and species. A Field trial was carried out at KALRO Kakamega and Alupe sites to determine the morphological characteristics and biomass yield of selected alternative fodder grasses (*Panicum maximum* and *Tripsacum laxum* and a Napier grass *cv Ouma*. These fodder grasses were subjected to three intervals of harvest and defoliations heights in a randomized complete block design arranged in a split-split plot and replicated three times at both study sites. The main plot effect was frequency of harvest while the sub-sublot effect was the defoliation height and the sub-sub-plot effect was the species. The data was subjected to analysis of variance and means separated by Dunan's Multiple Range Test at 5% level of significance. The results showed that a 4-weekly interval of harvest alongside defoliation heights of 10 cm and 15 cm influenced the highest cumulative biomass yield in Napier grass *cv Ouma* (38.47and 33.90 t/ha/year respectively) compared to *Tripsacum laxum* and *Panicum maximum* (23.3 t/year and 27.4 t/ha/year respectively). The effect of 4-weekly interval of harvest alongside defoliation height of 10 cm on *Panicum maximum* out-yielded *Tripsacum laxum* and this was attributed to earlier formation of stems in the former species than the later species, which increased the weight. More frequent harvests (4-weekly interval) alongside defoliation height of 10 cm above the ground cumulatively stimulated higher dry matter yield than other frequencies regardless of fodder species. This was attributed to regeneration of new tillers which contributed to biomass yield compared to infrequent *Tripsacum laxum* showed the largest Leaf Area Index (LAI) when harvested at 8-weekly and 12-weekly intervals alongside defoliation heights of 10 cm and this are attributed to the genetic characteristics of Trisacum laxum and also infrequent harvest limit interference with the growth of the crop. Napier grass *cv Ouma* harvested at 8-weekly interval alongside basal height of 10cm stimulated the widest canopy diameter growth at both sites. Napier grass *cv Ouma* attained the tallest height when harvested 12-weekly interval regardless of basal height harvested at Kakamega (242.06 cm) and Alupe (142.82 cm) sites. Among the alternative species, *Panicum maximum* and *Tripsacum laxum* equaled the heights at 12-weekly interval of harvest regardless of defoliation heights. The widest stool diameter was observed on Napier grass *cv Ouma* at 8-weekly interval of harvest alongside defoliation height of 10cm. Among the alternative fodder species *Panicum maximum* harvested at the frequency of 8 weeks regardless of defoliation heights influenced the widest stool diameter growth. Therefore, the study recommends *Panicum maximum* as an alternative fodder to Napier *cv Ouma* in terms of biomass yield at 4-weekly interval of harvest alongside defoliation height of 10 cm.

3.2 Introduction

In Sub-Saharan Africa, improved grasses and legumes have been recommended for livestock production due to their high dry matter yield as well as nutritive value (Onyeonagu and Asiegbu, 2013). *Andropogon gayanus*, *chloris gayana*, *Sorghum almum*, *Panicum maximum* and *Tripsacum laxum* are viewed as potential alternative fodder grasses to Napier grass in the dairy industry in East Africa and Western Kenya in particular (Orodho, 2006). Agronomic practices that can greatly affect biomass yield and morphological characteristics at various phenological stages are: forage species, frequency of harvest and stubble height after defoliation. Utilization of forages without appropriate consideration of frequency of harvest and basal defoliation height may interfere with re-growth of the harvested forage. Studies have shown variation of species in tolerance to frequency of harvest and intensity of defoliation due to differences in growth habits and root systems (Onyeonagu and Asiegbu, 2013, Wong *et al*., 2008).

In Western Kenya, the importance of biomass yield at different frequency of harvest, defoliation height and morphological characteristic of *Tripsacum laxum* and *Panicum maximum* as well as Napier grass *cv Ouma* is little known (Orodho, 2006). It is essential to know the stage of harvest as well as frequency of harvest because the quality and quantity of forage produced for animal feed is based on these factors (Ball *et al.*, 2001). However, the negative effect of Napier Stunt Disease (NSD) to Napier grass has led to the search for new clones that are tolerant to the disease hence the need to understand their physiological response to defoliation stress and biomass productivity more than other alternative fodder species. Alternative fodder species have been found to be tolerant to Stunt disease (Wamalwa, 2013) but their adoption in the dairy farming system of Western Kenya are limitedly understood, possibly because of greater emphasis previously placed on Napier grass, which is under threat from Stunt and Smut diseases (Jones *et al.*, 2004). Therefore, two candidate alternative fodder grasses Guinea grass (*Panicum maximum* Schum) and Guatemala grass *(Tripsacum laxum* Scrib and Merr) and a Napier *cv Ouma* were selected from an earlier study that was conducted at KALRO Kakamega with regard to morphological characterization of over 300 fodder grass accessions that were collected from various agro-ecological zones in Eastern, Coast and Western Kenya (Regional Dairy Centre of Excellence, 2012). Napier *cv Ouma*, Guinea grass (*Panicum maximum* Schum.) and Guatemala grass (*Tripsacum laxum* Scrib and Merr) are tolerant to Napier Stunt Disease (Wamalwa, 2013). Napier grass *cv Ouma* was identified from a farmer known as Ouma in Busia County by plant breeders at ICIPE, which was thoroughly screened and selected against phytoplasma from local accessions (Wamalwa, 2013). However, these species required further investigation for biomass production and morphological characteristics when subjected to frequencies of basal defoliation heights in two diverse agro-ecological zones. The disease free plantlets were planted at KALRO Kakamega on a land that had remained fallow for three consecutive seasons, to ensure that there was no contamination.

3.3 Objectives of the study

i. Determine the biomass yield of *Panicum maximum* and *Tripsacum laxum* to Napier grass *cv* Ouma in response to frequency of harvest and basal defoliation height.

ii. Determine morphological characteristics of the alternative fodder species to Napier in response to frequency of harvest and basal defoliation height.

3.4 Materials and methods

3.4.1 Experimental location, climate and soil

The study was conducted in two diverse Agro-ecological zones in Western Kenya, where smallholder dairy farming is practiced. The two Agro-ecological zones were high and medium, thus KALRO Kakamega in Kakamega County and KALRO Alupe in Busia County (Figure 1). The KALRO Kakamega site represent the Low Midlands 2 (LM 2) with an altitude of approximately 1430 m asl (Jaetzold *et al.*,2005). Kakamega site receives a bimodal rainfall, with long rains occurring from March to June and the short rains from August to November, totaling to 1500-1800 mm annually. Mean annual temperature range between 22^0C and 24^0C. The soils at the site were classified as Orthic Luvisols (Jaetzold *et al.*, 2005). The KALRO Alupe site is located in the Low Midlands 3 (LM 3) with an altitude approximately 1330 m asl (Jaetzold *et al.*,, 2005). The rainfall is bimodal allowing two cropping seasons, with the long rains starting from March ending in July and the short rains starting from August ending in November with a mean annual rainfall of 1200mm. Mean temperature ranges between 22^0C and 24^0C. The soils are Ferralsols/Nitisols, clayey, reddish, and deep and well drained (Jaetzold *et al.*,, 2005).

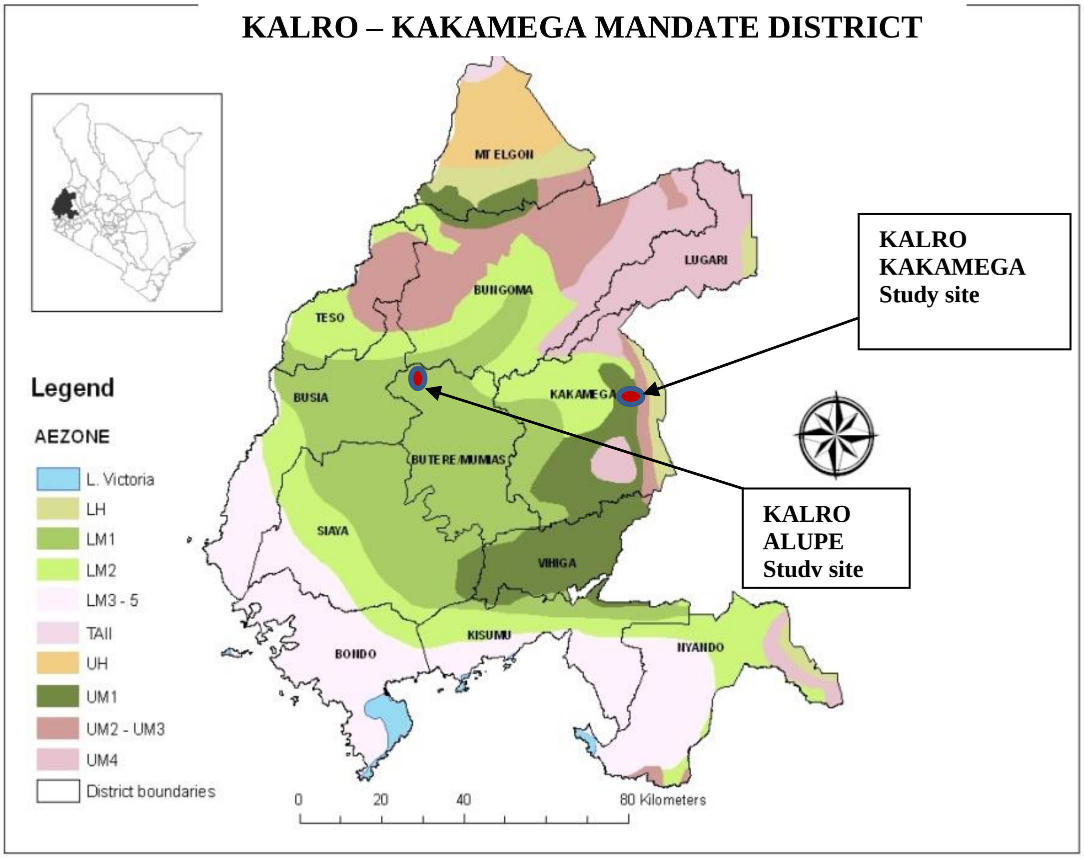


Figure 1 Sketch map showing experimental sites.Source: internet 2014

The physico-chemical characteristics of the soil at the depth of 0-15cm are shown in Table 2. The general soil texture for Kakamega site was sandy loam while at Alupe site was sandy clay loam soil. The soil pH for Kakamega and Alupe sites were 5.1 and 4.94 respectively which were classified as slightly acidic based on the critical value levels as recommended by Okalebo *et al.*, (2002). The organic carbon levels of soils at Kakamega and Alupe sites were 3.4% and 2.5% respectively. This implies that soil at Kakamega site is classified as highly in organic carbon and Alupe site as moderate (Okalebo *et al.*, 2002). Nitrogen content in the soil at Kakamega site was 0.2% while that of Alupe was 0.12%. The two sites contain moderate levels of Nitrogen content in the soil as classified by Okalebo *et al.*, (2002).

Table 1. Soil nutrient analysis at Kakamega and Alupe sites

Soil Attributes	Kakamega	Alupe
Soil pH (1:2.5 soil: water)	5.1	4.9
Organic C (%)	3.4	2.5
Total N (%)	0.2	0.12
Olsen P (mg kg^{-1})	7.0	6.4
Sand (%)	72	68
Clay (%)	18	22
Silt (%)	10	10
Textural Class	Sandy Loam	Sandy Clay Loam

The rainfall pattern during the study period is shown in Figure 2. The amount of rainfall received during the study period in 2012 LR and 2012 SR was 548 and 186 (Total 891.1mm) at Kakamega and 186 mm and 460 mm (Total 646mm) at Alupe. In 2013, Kakamega recorded 1064.3 mm in LR and 634.6 mm in SR (total 1698.9mm) while Alupe recorded 1190 in LR and 515 in SR (total 1705mm). The rainfall peaks coincided in May and August, a pattern expected in this area.

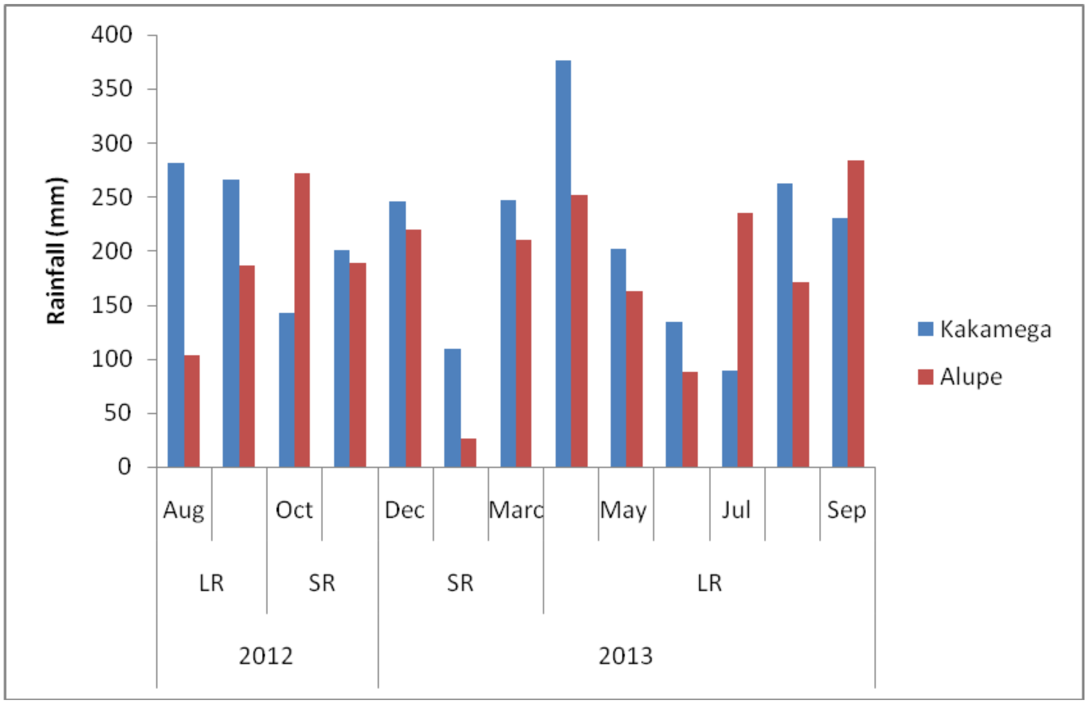


Figure 2: Rainfall distribution during the study period at Kakamega and Alupe sites. Source:Author 2014

As shown in Table 2, the hottest months at Kakamega site were observed in the months of January to March (29.9^{0}C to 29.6^{0}C) while the minimum temperature were in the months of August September (13.0^{0}C). Alupe site showed maximum temperature in the months of February, March and October (31^{0}C-32.7^{0}C).

Table 2 Temperature range during the study period at Kakamega and Alupe sites

Month	Kakamega site		Alupe site	
	Maximum (^{0}C)	Minimum (^{0}C)	Maximum (^{0}C)	Minimum (^{0}C)
Aug- 2012	26.3	13.9	30.3	15.3
Sep- 2012	26.9	13.9	30.8	16.0
Oct- 2012	27.4	14.8	31.4	16.6
Nov- 2012	27.2	14.6	31.0	17.0
Dec - 2012	27.2	14.4	29.0	16.3
Jan - 2013	28.6	13.9	26.0	15.3
Feb- 2013	29.9	14.2	31.1	17.0
Mar-2013	29.6	15.0	32.7	17.2
Apr-2013	27.1	15.4	31.0	17.7
May-2013	27.4	14.4	30.7	17.6
Jun - 2013	26.8	14.5	30.1	20.6
Jul- 2013	26.7	13.6	30.9	16.1
Aug-2013	26.4	13.9	30.1	17.0
Sep- 2013	27.2	14.0	31.0	17.5

3.4.2 Experimental treatment, design and plot lay out

a) Experimental treatments

The treatments consisted of three frequencies of harvest which were 4-weekly interval (F4), 8-weekly interval of harvest (F8) and 12 weekly interval of harvest (F12). Three defoliation heights were 5 cm (H5), 10 cm (H10) and 15 cm (H15). The fodder grass species were *Panicum maximum* Schum), *Tripsacum laxum* Scrib and Merr and Napier grass *cv Ouma*. Thus there were 27 treatments replicated three times.

b) Experimental design and plot lay out

The experimental design was randomized complete block design arranged in a split-split plot with three replications (Figures 3 and 4 at Kakamega and Alupe sites respectively).

This was a three-factor experiment where three levels of precision were required for the various effects (Gomez and Gomez 1984). The main-plot factor was the frequency of harvest and the sub-plot factor was basal defoliation height while the sub-sub-plot factor was the species. The main-plot treatment was randomly assigned in the main plot while the sub-plot treatment was also randomly assigned in the sub-plot. The sub-sub-plot treatment was randomly assigned in the sub-sub-plots.

The dimension for each main plot was 2 m x 27 m separated by 1.5 m while the dimension for each of the sub-plot was 2 m x 8 m separated by 1.5 m (Figures 3 and 4). The measurement for the sub-sub plot was 2 m x 2 m separated by 1m (Muia *et al*., 1999). A total of three blocks (Replicates) were established and separated by 1.5 m. The fodder grasses and a Napier grass were planted from the rooted splits to fast track the outcome of the study.

Block 1									Block 2								
F8H5 N **T1**	F8H5P **T2**	F8H5 G **T3**	F8H1 0P **T4**	F8H1 0N **T5**	F8H1 0G **T6**	F8H 15 G **T7**	F8H 15 N **T8**	F8H 15P **T9**	F4H1 5P **T10**	F4H1 5N **T11**	F4H1 5G **T12**	F4H1 0N **T13**	F4H1 0G **T14**	F4H10 P **T15**	F4H 5G **T16**	F4H 5P **T17**	F4H 5N **T18**
F4H1 5G **T18**	F4H15 P **T17**	F4H15 N **T16**	F4H1 0P **T15**	F4H1 0 N **T14**	F4H1 0G **T13**	F4H 5P **T12**	F4H 5N **T11**	F4H 5G **T10**	F8H1 5P **T9**	F8H1 5G **T7**	F8H1 5N **T8**	F8H5 G **T3**	F8H5 N **T1**	F8H5 P **T2**	F8H1 0N **T5**	F8H1 0P **T4**	F8H 10 G **T6**
F12H 10P **T19**	F12H1 0N **T20**	F12H1 0G **T21**	F12H 15P **T22**	F12H 15G **T23**	F12H 15 N **T24**	F12 H5P **T25**	F12 H5G **T26**	F12 H5N **T27**	F12H 10P **T10**	F12H 10N **T11**	F12H 10G **T12**	F12H 15P **T13**	F12H 15G **T14**	F12H1 5N **T15**	F12H 5G **T16**	F12H 5P **T17**	F12 H5N **T18**

Block 3								
F4H5 P **T23**	F4H5 N **T26**	F4H5 G **T27**	F4H1 5P **T20**	F4H1 5N **T21**	F4H1 5G **T19**	F4H 10 N **T23**	F4H 10G **T23**	F4H 10P **T22**
F12H 10P **T10**	F12H1 0N **T11**	F12H1 0G **T12**	F12H 15P **T13**	F12H 15 N **T15**	F12H 15 G **T14**	F12 H5N **T18**	F12 H5G **T16**	F12 H5P **T17**
F8H5 G **T3**	F8H5 N **T1**	F8H5 P **T2**	F8H1 5 N **T8**	F8H1 5 G **T7**	F8H1 5P **T9**	F8H 10G **T6**	F8H 10 N **T5**	F8H 10P **T4**

1.5m

2 m

2m

8m

27m

Figure 3 Plot lay out for KALRO Kakamega site

Source:Author 2014

Block 1								
F8 H5 N**T1**	F8 H5 P **T2**	F8 H5 G **T3**	F8H10P **T4**	F8 H10 N **T5**	F8 H10 G **T6**	F8 H15 G **T7**	F8 H15 N **T8**	F8 H15 P **T9**
F4 H15G **T18**	F4 H15 P **T17**	F4 H15 N **T16**	F4 H10 P **T15**	F4 H10 N **T14**	F4 H10 G **T13**	F4 H5 P **T12**	F4 H5 N **T11**	F4 H5 G **T10**
F12 H10 P **T19**	F12 H10 N **T20**	F12 H10 G **T21**	F12 H15 P **T21**	F12 H15 G **T23**	F12 H15 N **T24**	F12 H5 P **T25**	F12 H5 G **T26**	F12 H5 N **T27**
Block 2								
F12 H10 P **T19**	F12 H10 N **T20**	F12 H10 G **T21**	F12 H15 P **T21**	F12 H15 G **T23**	F12 H15 N **T24**	F12 H5 G **T26**	F12 H5 P **T25**	F12 H5 N **T27**
F8 H15 P **T9**	F8 H15 G **T7**	F8 H15 N **T8**	F8 H5 G **T3**	F8 H5 N **T1**	F8 H5 P **T2**	F8 H10 N **T5**	F8 H10 P **T4**	F8 H10 G **T6**
F4 H15 N **T12**	F4 H15 P **T11**	F4 H15 G **T10**	F4 H10 N **T14**	F4 H10 G **T15**	F4 H10 P **T13**	F4 H5 G **T18**	F4 H5 P **T16**	F4 H5 N **T17**
Block 3								
F4 H15 P **T11**	F4 H15 N **T12**	F4 H15 G **T10**	F4 H5 P **T16**	F4 H5 N **T17**	F4 H5 G **T18**	F4 H10 N **T14**	F4 H10 G **T15**	F4 H10 P **T13**
F12 10 N **T20**	F12 H10 P **T19**	F12 H10 G **T21**	F12 H15 P **T21**	F12 H15 N **T24**	F12 H15 G **T23**	F12 H5 N **T27**	F12 H5 G **T26**	F12 H5 P **T25**
F8 H5 G **T3**	F8 H5 N **T1**	F8 H5 P **T2**	F8 H15 N **T8**	F8 H15 G **T7**	F8 H15 P **T9**	F8 H10 G **T6**	F8 H10 N **T5**	F8 H10 P **T4**

1.5m

2m

8m

2m

27m

Figure 4 Plot lay out for KALRO Alupe site.Source:Author 2014

Treatments key

T1 = 8-Weekly interval of harvest alongside defoliation height of 5 cm for Napier grass
T2 = 8-Weekly interval of harvest alongside defoliation height of 5 cm for Panicum grass
T3 = 8-Weekly interval of harvest alongside defoliation height of 5 cm for Guatemala grass
T4 = 8-Weekly interval of harvest alongside defoliation height of 10 cm for *Panicum maximum*
T5 = 8-Weekly interval of harvest alongside defoliation height of 10 cm for Napier grass
T6 = 8-Weekly interval of harvest alongside defoliation height of 10 cm for Guatemala grass
T7 = 8-Weekly interval of harvest alongside defoliation height of 15 cm for Guatemala grass
T8 = 8-Weekly interval of harvest alongside defoliation height of 15 cm for Napier grass
T9 = 8-Weekly interval of harvest alongside defoliation height of 15 cm for *Panicum maximum*
T10 = 4-Weekly interval of harvest alongside defoliation height of 15 cm for Guatemala grass
T11 = 4-Weekly interval of harvest alongside defoliation height of 15 cm for *Panicum maximum*
T12 = 4-Weekly interval of harvest alongside defoliation height of 15 cm for Napier grass
T13 = 4-Weekly interval of harvest alongside defoliation height of 10 cm for *Panicum maximum*
T14 = 4-Weekly interval of harvest alongside defoliation height of 10 cm for Napier grass
T15 = 4-Weekly interval of harvest alongside defoliation height of 10 cm for Guatemala grass
T16 = 4-Weekly interval of harvest alongside defoliation height of 5 cm for *Panicum maximum*
T17 = 4-Weekly interval of harvest alongside defoliation height of 5 cm for Napier grass
T18 = 4-Weekly interval of harvest alongside defoliation height of 5 cm for Guatemala grass
T19 = 12-Weekly interval of harvest alongside defoliation height of 10 cm for *Panicum maximum*
T20 = 12-Weekly interval of harvest alongside defoliation height of 10 cm for Napier grass
T21 = 12-Weekly interval of harvest alongside defoliation height of 10 cm for Guatemala grass
T22 = 12-Weekly interval of harvest alongside defoliation height of 15 cm for Panicum grass
T23 = 12-Weekly interval of harvest alongside defoliation height of 15 cm for Guatemala grass
T24 = 12-Weekly interval of harvest alongside defoliation height of 15 cm for Napier grass
T25 = 12-Weekly interval of harvest alongside defoliation height of 5 cm for Guatemala grass
T26 = 12-Weekly interval of harvest alongside defoliation height of 5cm for *Panicum maximum*
T27 = 12-Weekly interval of harvest alongside defoliation height of 5 cm for Napier grass

3.4.3 Establishment of field experiment and management

The experimental field had stayed fallow for the last three seasons at the time of starting the experiment. The field was ploughed to the depth of 15 cm, targeting the top soil. The field was further re-ploughed to attain fine soil texture. The ploughed experimental field was then marked according to the design, followed by digging of holes at the depth of 15 cm and 15 cm wide (Orodho, 2005). Rooted splits were uprooted from the parent field with careful attention observed to ensure that the roots and germinating buds were not damaged. In the case of *Panicum maximum*, three tillers which were firmly attached to a common root crown were uprooted, with minimal interference with the rooting system (Ramadhan *et al* ., 2012). However, in the case of Napier *cv ouma* and *Tripsacum laxum*, only one tiller carrying its roots system was carefully uprooted (Muia *et al*., 1999). The uprooted planting materials were immediately transported to the experimental plots and planted to minimize wilting and drying of the soil in the prepared holes. In each sub-sub plot, 25 root splits of alternative fodder species were planted, while Napier grass *cv Ouma* carried 15 root splits. The separation between the rows for alternative grasses was 0.5m while for Napier was 1m (Ramathan et al., 2012, (Muia *et al*., 1999). Recommended fertilization rate of 100kg/ha of DAP, was applied at planting and top-dressed with 100kg/ha of CAN repeatedly after every defoliation to minimize the local soil nutrients influence on the performance of the fodder species.

Prior to planting, top soil (depth 15cm) from three points in each replicate was randomly collected, thoroughly mixed to form a composite. The same soil sampling procedure was applied for the Alupe experimental plots. The sub-sample of the soil was air dried and ground to pass through a 2mm sieve. The soil samples were analyzed at KALRO Kakamega laboratory for pH, organic carbon, total nitrogen and available phosphorus and textural class using procedures outlined in Okalebo *et al.,* (2002). The experiment in each agro-ecological zone was independently considered and analyzed because of the expected variations in abiotic and biotic factors.

One month after planting, all the plants were cutback to a basal stubble height of 5 cm to standardize the stubble height. Before recording the production yield for each species at respective frequencies alongside defoliation heights, morphological parameters of leaf area index, plant height, canopy diameter, stool diameter, leaf length, leaf width, leaf numbers and number of tillers were determined as described below.

3.4.4 Parameters measured

a) Dry matter (Aboveground biomass)

Three middle rows consisting of nine internal stools of *Panicum maximum* and *Tripsacum laxum* while one middle row consisting of Napier *cv Ouma* were hand-clipped at their respective defoliation heights and interval of harvest immediately after collecting morphological data. At 4, 8 and 12-weekly interval of harvest, three defoliation height of 5cm, 10 cm and 15 cm for each forage grass were manually clipped and weight using electronic balance. Leaves and stems were separated manually from the clipped samples and subsequently chopped into small pieces (about 3 cm lengths) weighing about 500 g. The samples were oven dried at 60^0C for 48 hours to obtain dry matter. The same procedure was conducted for samples harvested at 8-weekly and 12 weekly intervals.

Dry matter yield was calculated using the following formula:

1. If the sample forage yield before drying weight 85 Kg
2. After drying the sample weight 25 Kg
3. Then, % dry mater of the sample = 25/85 = 29.4%
4. (As is yield) x % dry matter = dry matter yield
5. If the harvest was 23 tons/acre of forage is 29.4% dry matter
6. Then, 23 x 29.4% = 6.76 tons of dry matter per acre

b) Stool diameter

This is the measurement of the root crown, which was taken from the surface of the ground. The purpose was to determine the diameter of the root crown as the plant is subjected to the various treatments. A graduated tape measure was stretched across the root crown of the plant and measurements were recorded. Two measurements were taken per stool, thus the widest and shortest diameter then mean calculated. Three stool diameter observations were made on Napier grass while nine were recorded for *Panicum maximum* and *Tripsacum laxum*. The measurement schedules were in accordance with design. A 4-weekly interval of measurement was repeated nine times, 8-weekly interval was repeated five times while three times of measurement was recorded for the 12-weekly interval of harvest throughout the experimental period of two years.

c) Plant height

The plant height was determined by using graduated ruler in centimeters by being positioned at the surface ground inclining on the tallest tiller per stool in each plot, excluding the guard rows. The aim was to measure the highest plant. This measurement occurred at designed frequency of harvest alongside defoliation height. The plant height measurement for 4-weekly interval of harvest was repeated nine times while for 8-weekly interval was repeated five times and 12-weekly interval was repeated three times for the 2-year experimental period. This treatment occurred before cutting down of the fodder species for dry matter determination. On Napier, three stools were measured per frequency of harvest while for *Tripsacum laxum* and Panicum, nine stools were measured.

d) Basal tillers

The basal tillers were evaluated by counting tillers from the three stools of Napier grasses and nine stools of *Panicum maximum* and *Tripsacum laxum* at each frequency of harvest, thus 4-weekly, 8-weekly and 12-weekly intervals. The counting was done prior to cutting for measurement of biomass yield. By end of the experimental period, nine repeated counts for a 4-weekly interval of harvest, five for 8-weekly interval and three for 12-weekly interval of harvest were done.

e) Leaf blade length

This was achieved by measuring the third leaf on the tallest tiller. Using graduated ruler, three measurements were taken from each leaf, starting from the base of the leaf. Three leaf lengths were recorded for Napier grass while nine were recorded for *Panicum maximum* and *Tripsacum laxum*. The measurement was taken according to the frequency of harvest, thus 4-weekly interval of harvest nine measurements, 8-weekly interval five measurements and 12-weekly interval three measurements.

f) Leaf blade width

This was achieved by measuring the third leaf on the tallest tiller. Using graduated ruler in centimeters, three measurements were taken from each leaf, thus, near the tapering tip end, middle and near tapering base end of the leaf. The mean of the three measurements was calculated to obtain leaf width size. The three leaf width sizes were recorded for Napier grass while nine were recorded for *Panicum maximum* and *Tripsacum laxum*. The measurement was taken according to the frequency of harvest, thus 4-weekly interval of harvest nine repeated measurements were done while 8-weekly interval for five measurements and 12-weekly interval three measurements.

g) Leaf numbers

This parameter was measured by counting number of leaves on the tallest tiller per stool. This was achieved by counting leaves on three tillers on three stools for Napier and nine stools for *Panicum maximum* and *Tripsacum laxum*. The counting was done based on the frequency of harvest. A 4-weekly interval of harvest, nine counts were taken while 8-weekly interval 5 counts were taken and 12-weekly interval three counts were taken throughout the experimental period.

h) Leaf Area Index (LAI)

The leaf area index was estimated directly using canopy analyzer by LI-COR, Model LAI, 2000. One reading was made under canopy of each plot by positioning the device at

50 cm from the clump base in each reading, so the space between the rows was covered by the readings. The readings were made before the defoliation was done and every season of harvest.

3.5 Statistical model (split-split plot)

The statistical model for the field experiment is presented below and the ANOVA skeleton is shown in Table 3.

- $Y_{ijkl} = \mu + ri + f_j + \alpha_{ij} + h_k + f_{hjk} + \beta_{ijk} + s_l + sf_{jl} + sh_{kl} + shf_{ikl} + Y_{ijkl}$

Where:

- μ - fixed general effects (population mean)
- ri – Block effect
- f_j – Effect of frequency of defoliation
- α_{ij} – Main plot Error (Error a)
- h_k – Effect of defoliation height
- fh_{jk} – Interaction between frequency of harvest and defoliation height
- β_{ijk} – Split Plot Error (Error b)
- Si– Effect of Species
- sf_{jl} –Interaction between species and frequency of harvest
- sh_{jk} – Interaction between species and defoliation height
- shf_{ikl} – Interaction between species and defoliation height and frequency of harvest
- Y_{ijkl} – Split-Split Plot Error (Error c)

Table 3. Outline of ANOVA for Split-split plot design

Source of variation	Degree of freedom	Sum of squares	Mean square	Computed F	Tabular F 5%
Main plot-plot analysis:					
Replication	r-1 = 2				
Main plot factor – Frequency of	f-1 = 2				
harvesting (F)	(r-1) (f-1) = 4				
Error (a)					
Sub-plot analysis:					
Sub-plot factor - Height of	h-1 = 2				
defoliation (H)	(f-1)(h-1) = 4				
F x H	f(r-1)(h-1)=12				
Error (b)					
Sub-subplot analysis:					
Sub-subplot analysis factor –	s-1=2				
Species (S)	(f-1)(h-1)=4				
F x S	(h-1)(s-1)=4				
H x S	(f-1)(h-1)(s-1)=8				
F x H x S	fh(r-1)(s-1)=36				
Error (c)					
Total = F x H x S	rfhs= 80				
Interaction effect = (F*H) +(F*S) + (H*S) + (F*H*S)					

3.6 Data analysis

Statistical analysis was done using the Statistical Analysis System (SAS), (1990). The data was subjected to analysis of variance (ANOVA) and the interaction meas separated using Duncan's Multiple Range Test (DMRT) as described by Steel and Torrie, (1980).at 5% level of significance.

3.7 Results and Discussion

The results of the analysis of forage yield and morphological characteristics of the field experiment are presented hereunder.

3.7.1 Effect of harvest frequency, defoliation height and forage species on biomass yield

The Analysis of variance (ANOVA) results showed a significant ($p \leq 0.05$) interaction between frequency of harvest, defoliation heights and fodder species in cumulative biomass yield at Kakamega and Alupe sites (Appendix Iand II). As shown in Table 4, Napier grass *cv Ouma* significantly ($p \leq 0.05$) out-yielded *Tripsacum laxum* and *Panicum maximum* when harvested at a 4-weekly intervals alongside defoliation height of 10 cm above ground (38.5 t/ha/yr) followed by the same species harvested at 4-weekly interval but defoliated at 15 cm stubble height (34 t/ha/year) at Kakamega site. This result indicated that Napier grass *cv Ouma* produced higher dry matter yield than what was reported by Muyekho *et al.,* (2003) on most promising Napier cultivars such as Kakamega 1, Kakamega 3, French Cameroon and Clone 13, which yielded between 15 to 22 t/ha/yr. However, *Panicum maximum* harvested at 4 weekly interval alongside basal defoliation height of 10 cm yielded 27.5 t/ha/year that was not significantly different from Napier grass *cv Ouma* (28.9 t/ha/year) when harvested at 8 weekly interval alongside basal defoliation height of 10 cm. *Panicum maximum* out-yielded (27.4 t/ha/year) *Tripsacum laxum* (23.3 t/year) when harvested at 4-weekly interval alongside defoliation height of 10 cm. Similar trends were observed for Alupe site (Table 5). This could be explained by cumulative biomass yield as a result of twelve repeated harvest for the 4-weekly intervals of harvest compared to six repeated harvests for 8-weekly interval of harvest and also three repeated harvest for 12-weekly intervals of harvest in two years of the experiment. This could also be associated with large number of tillers which formed more leaves compared to forage species harvested at 8 and 12-weekly intervals (Mullahey *et al.,* 1990). The trend of increased dry matter yield with more frequent interval of harvest in this study is in agreement with the findings of (Saddul *et al*., 2004 and Kilcher, 1981) who obtained increased biomass yield with increased intervals of harvest. Furthermore, Hsu, (2005) established that Nile grass (*Acroceras macrum* Stapf) and Pangola grass (*Digitaria eriantha* Steud) increased biomass yield with increased frequencies of cutting. In contrast, extended interval of harvest of 12-weekly and 8-weekly interval yielded less, mainly because more re-growth and tillering is promoted by more frequent harvest (Hoglind *et al*., 2005) which was not the case for this treatment. Ruiz *et al*., (2012) attributed the less biomass yield as a result of longer intervals between the harvest to the aging of the leaves and a great number of them fall down due to senescence. Njarui *et al.,* (2008) found Napier grass yielding more than *Panicum maximum* due to differences in re-growth vigor after defoliation while Stichler and Bade, (2002) found the stage of plant growth important in determining the biomass yield. In his research on frequency and basal defoliation height on biomass production of *Tithonia diversifolia,* Hsu, (2005) reported that plants cut at 5cm and more frequently performed least in terms of biomass yield. This was associated with leafing and tillering ability since the plants cut at this height and frequency has fewer food reserves in the stems for the next re-growth.

The yield for *Panicum maximum* at 4-weekly interval of harvest alongside defoliation height of 10 cm did not significantly differ from Napier grass *cv Ouma* when harvested at a frequency of 8 weeks along site defoliation height of 10 cm. This finding suggests that *Panicum maximum* has a potential of being an alternative fodder to Napier grass in Western Kenya when harvested at 4-weekly interval alongside defoliation basal height of 10 cm in the absence of Napier grass stunt disease tolerant varieties. In addition , Zavata *et al*., (2007) observed that high yields for forages harvested at the frequency of 4-weeks were highly palatable and therefore large quantity is grazed. Although Napier grass cv *Ouma* is more tolerant to Stunt disease (Khan personal communication), this study has shown that the biomass yield is comparable with other Napier species that are susceptible to Stunt and Smut diseases (Wamalwa, 2013, Muyekho *et al.,* 2006).

At Alupe site Napier grass *cv Ouma* harvested at 4-weekly interval alongside defoliation height of 10 cm above the ground yielded the highest biomass (34.98 t/ha/yr). This was below the yield observed at Kakamega site. This could be attributed to variation in climatic conditions between Alupe and Kakamega, where Alupe received lower rains than Kakamega throughout the study period. Baatar, (2008) and Saddul *et al.,* (2004) reported similar findings of forage yield variations between geographical locations due to differences in climatic patterns. In the current study, Kakamega site experienced relatively higher rainfall (1295 mm/year) than Alupe (1175mm/year) and this may have stimulated vigorous tillering ability, leaf numbers, wider canopy formation and stool diameter as is demonstrated in the highly positive correlation between these parameters and biomass yield (Table 29). Breshears and Bainers, (1999) found related findings that biomass yield of forage species progress with available soil moisture and diminish with the fall of moisture below field capacity and ceases at the permanent wilting percentage. Cameron, (2001) and Bahmani, (1999) further reported that soil water stress may lead to limited leaf area development and consequently reduce dry matter yield.

Table 4. Interaction between frequency of harvest, defoliation height and species on cummulative dry matter yield at Kakamega site for 12 months

Frequency of harvest (weeks)	Defoliation height (cm)	Dry matter yield t/ha/year		
		Tripsacum laxum	Napier *cv ouma*	*Panicum maximum*
4	5	16.6hi	24.50de	16.4hi
	10	23.3e	38.5a	27.5c
	15	20.7f	33.9b	23.1e
8	5	14.9ij	23.7de	10.3m
	10	15ij	28.9c	13.1kl
	15	14.5jk	25.2d	13kl
12	5	8.5n	18gh	13kl
	10	12.2l	19.3fg	12.4m
	15	12.7kl	23e	8.9n
$DMRT_{0.05}$ = 1.66, CV% = 5.34				

Note: Means marked by different letters are significantly different at p≤0.05 significance level

Table 5. Interaction between frequency of harvest, defoliation height and species on cumulative dry matter yield at Alupe site

Frequency of harvest (weeks)	Defoliation height (cm)	Dry matter yield t/ha/year		
		Tripsacum laxum	Napier *cv Ouma*	*Panicum maximum*
4	5	12.9ij	25.4d	17.9g
	10	19.7f	35a	25.4d
	15	14.3h	32.2b	20.7f
8	5	12jk	24e	9.7mn
	10	13.7hi	27.6c	11.5kl
	15	13.0ij	26.7c	11.2kl

12	5	9.3no	17.2g	7.9pq
	10	8.6op	20.4f	9.6mn
	15	10.7lm	20.4f	7.1q
$DMRT_{0.05}$ = 1.07, CV% = 3.56				

Note: Means marked by different letters are significantly different at p≤0.05 significance level using DMRT

3.7.2 Morphological characteristics in response to treatments

a) Leaf Area Index (LAI) per plot

The largest LAI was observed on *Tripsacum laxum* when harvested at 12-weekly (3.6) and 8-weekly (3.4), regardless of defoliation height in October 2012 (Table 6). The ANOVA results revealed a significant (p≤0.05) interaction between frequency of harvest and fodder species for leaf area index in the months of October, February and June (Appendices 4, 5 and 6 at Kakamega site and (Appendices XXI, XXII and XXIII at Alupe site). *Tripsacum laxum* harvested at 8 and 12-weekly interval significantly (p≤0.05) increased LAI in October, February and June compared to Napier grass *cv Ouma* and *Panicum maximum* regardless of defoliation heights. This trend was also observed in the month of February. However, larger LAI was showed in the months of June than other months. This could be attributed to higher moisture levels in the month of June than other two months, which stimulated formation of many tillers (Table 13). Although similar trends were observed for the Alupe, three interaction effects were observed in the month of June 2013 (Table 7). *Tripsacum laxum* harvested at 8-weekly interval alongside defoliation height of 5cm and at 8-weekly interval alongside defoliation height of 10cm showed significantly the highest LAI of 4.0 at Alupe site. The results in the current study for *Tripsacum laxum* maintaining the largest LAI could be associated with the natural morphological characteristics of the plant as well as environmental adaptation leading to morphological behavior observed from the influence of the treatment effects. Erkovan *et al.,* (2009) found ideal LAI among forage crops to range between 3 and 11 depending on the morphological and anatomical structure of species, which is appropriate for intercepting 95% of photosynthetically active radiation to realize maximum dry matter production (Brougham, 1956 cited in Coelho *et al.,* 2014), though vary between species and within species as the season fluctuates (Engel *et al.*, 1987). Leaf Area Index for *Tripsacum laxum* and Napier *cv Ouma* regardless of the frequency of harvest and defoliation height in this study satisfied the ideal range recommended by Erkovan *et al.,* (2009). It was possible to achieve this limit for *Panicum maximum* by the influence of 12-weekly interval of harvest alongside defoliation height of 10cm. Leaf area index drives both within and below-canopy microclimate, determines and controls canopy water interception, radiation extinction, and water and carbon gas exchange and is, therefore, a key component of biogeochemical cycles in ecosystems (Sandhu *et al.* 2012). Therefore adequate LAI that ranges from 3 to 11 is critical to plant regeneration for constant primary production (Carpici, 2011).

Table 6. Interaction between frequency of harvest and species on LAI at Kakamega site

Season	Frequency of harvest (weeks)	Leaf Area Index Species		
		Tripsacum laxum	Napier*cv Ouma*	*Panicum maximum*
October 2012	4	3.2b	3.1bc	1.4e
	8	3.4ab	3.2b	2.5d
	12	3.6a	3.4b	3.1bc
$DMRT_{0.05}$ = 0.23, CV% =7.55				
February 2013	4	3.2b	3.2b	2.1d
	8	3.6a	3.2b	2.5c
	12	3.7a	3.4b	3.3b
$DMRT_{0.05}$ = 0.18, CV% = 5.78				
June 2013	4	3.8cd	3.6d	2.9e
	8	3.8cd	3.9bc	3.6d
	12	4.4a	4.1b	3.6d
$DMRT_{0.05}$ = 0.23, CV %= 5.96				

Note: Means marked by different letters are significantly different at p≤0.05 significance level using DMRT

Table 7. Interaction between frequency of harvest, defoliation height and species on LAI at Alupe site during wet season in June, 2013

Frequency of harvest (weeks)	Defoliation height (cm)	Leaf Area Index Species		
		Tripsacum laxum	Napier*cv Ouma*	*Panicum maximum*
4	5	3.3def	3.4cdef	2.6j
	10	3.3def	3.3efg	2.8ij
	15	3.3def	3.0ghi	2.8hij
8	5	4.0a	3.7abc	3.4cdef
	10	4.0a	3.7abc	3.5cde
	15	3.9ab	3.6bcd	3.5cde
12	5	3.6bcd	3.6bcd	3.1fgh
	10	3.4def	3.5cde	3.0ghi
	15	3.6bcde	3.5cde	2.9hij
$DMRT_{0.05}$ = 0.28, CV% = 5.37				

Note: Means marked by different letters are significantly different at p≤0.05 significance level

b) Plant height per tiller

The ANOVA results showed a significant interaction ($p \leq 0.05$) between frequency of harvest and forage species in October at Kakamega site in terms of plant height (Appendix 7). However, significant interaction was shown between frequency of harvest, defoliation height and forage species at Kakamega site in, February, June (Appendices 8 and 9 respectively) and in October, February and June at Alupe site (Appendices XXIV, XXV, XXVI respectively). Napier grass *cv Ouma* was significantly influenced ($p \leq 0.05$) by 12-weekly intervals of harvest than other frequencies of harvest and forge species regardless of defoliation height in terms of plant height, which showed plant height of 242.1 cm and 142.8 cm at Kakamega and Alupe sites respectively in October (Table 8 and 9 respectively). This significant interaction ($p \leq 0.05$) between frequency of harvest and fodder species in plant height for the wet season (October) and dry season (February) at Kakamega and Alupe sites was supported in the ANOVA results (Appendix 8 and 9 respectively). These high values might be attributed to undisturbed growth of plants by cutting or for forage remaining for long period of growth without harvest (Zewdu *et al.*, 2003). However, due to less tillering ability in a 12-weekly interval of harvest and infrequent intervals of harvest, less cumulative biomass yield was observed compared to a 4-weekly interval of harvest alongside 10 cm defoliation height (Tables 4 and 5). This was also reported by Daher *et al.*, (2004) on elephant grass that plant height influences dry matter production especially in cases of clones with high tillering capacity. They also found that leaf numbers per tiller has a positive influence on dry matter yield.

A 12-weekly interval of harvest significantly ($p \leq 0.05$) influenced *Panicum maximum* height more than *Tripsacum laxum* as alternative fodder species regardless of defoliation height at both Kakamega and Alupe sites in October (Tables 8 and 9 respectively). Comparable results were observed for the months of February on Napier *cv Ouma* and *Panicum maximum* despite the fact that relatively short heights were observed in October when harvested at 8 and 12 weekly interval of harvest at Kakamega and Alupe sites (Table 8 and 9). The general trend for the plant in June showed increase in height at Kakamega and Alupe study sites (Tables 10 and 11). Napier *cv Ouma* maintained significantly the tallest when harvested at 12-weekly interval alongside defoliation height of 5 cm (304.4 cm) and 10 cm (306.1 cm) at Kakamega site (Table 10 and comparable results were observed for the Alupe site Table 11). Comparable trends were observed for Napier *cv Ouma* at Alupe site in June but relative short heights was observed. Napier *cv Ouma* was the tallest (262.1 cm) when harvested at 12-weekly interval relative to defoliation heights of 10 cm and 5 cm (Table 11). Onyeonagu and Asiegbu, (2013), observed similar results that infrequent harvests of fodder grasses influenced plant height increase over situations where cutting was frequent. It may also be attributed to inability of grasses harvested at high intensity to replenish leaves, set seeds and store food reserves in their roots, thereby reducing plant growth (Adams *et al.*, 1991).

Panicum maximum was the tallest among the alternative species when harvested at 12-weekly interval, which ranged from 184.3 cm to 191.6 cm at Kakamega site and 178.1 cm to 201.9 cm plant height at Alupe site in the month of June. The variation in height among the species could be associated with better adaptation of Napier *cv Ouma* at both Kakamega and Alupe sites and inherent genetic factors than other species hence their outstanding performance in height growth. Moreover, increase in height with infrequent harvesting may be attributed to longer vegetative growth period of fodder plants (Ishaque and Bukhsh, 2010). Similar findings were observed by Mushtaque *et al.,* (2009) who observed that *Cenchrus ciliaris* and *Panicum maximum* when harvested infrequently during the growing season produced taller plants than those clipped frequently, which was attributed to longer vegetative growth periods.

More frequent harvest of the forage species (4-weekly interval of harvest) significantly affected the plant heights, giving the shortest height compared to less frequently harvested intervals. It however influenced more biomass yield than the case of delayed harvest and this was associated with high tillering ability and cumulative yield due to more frequent harvests (Table 4 and 5). The observed decrease in the height of fodder species with increase in cutting frequency alongside defoliation height agrees with the report by Adams *et al.*, (1991) who found that frequent grazing of Himalayan grasslands by a number of cattle reduced the ability of the grass to replenish leaf area, set seeds and store food reserves in their roots, thereby reducing plant growth. Santos *et al*., (2013) suggested that short plants are preferred by animals due to their higher rates of green leaf blades which are the morphological component of pasture with the best nutritional values. Furthermore, taller plants are not preferred for feeding animals because they usually feature greater stem and senescent tissue mass (Santos *et al.,* 2013), which have lower nutritional value as shown in the current study.

Table 8 Interaction between frequency of harvest and species on plant height at Kakamega site

Season	Frequency of harvest (weeks)	Plant height (cm) Species		
		Tripsacum laxum	Napier *cv Ouma*	*Panicum maximum*
October 2012	4	42.9g	82.8e	61.8f
	8	65.2f	145.8b	85.5e
	12	96.8d	242.1a	109.0c
$DMRT_{0.05}$ = 5.18, CV% = 5.42				
February 2013	4	68.6e	88.9d	80.5de
	8	80.7de	156.7b	86.5d
	12	104.9c	225.4a	107.0c
$DMRT_{0.05}$ =12.8, CV% =11.2				

Means marked by different letters are significantly different at p≤0.05 significance level

Table 9 Interaction between frequency of harvest and species on plant height at Alupe site

Season	Frequency of harvest (weeks)	Plant height (cm) Species		
		Tripsacum laxum	Napier *cv Ouma*	*Panicum maximum*
October 2012	4	43.0h	80.7e	50.7g
	8	64.4f	104.4c	86.2d
	12	81.6e	142.8a	108.6b
$DMRT_{0.05}$ = 4.05, CV% = 4.99				
February 2013	4	57.9g	88.7de	85.9e
	8	65.6f	115.1b	92.9d
	12	92.2d	243.8a	109.2c
$DMRT_{0.05}$ = 1.6, CV% = 4.6				

Means marked by different letters are significantly different at p≤0.05 significance level

Table 10 Interaction between frequency of harvest, defoliation height and species on plant height at Kakamega site in June 2013

Frequency of harvest (weeks)	Defoliation height (cm)	Plant height (cm) Species		
		Tripsacum laxum	Napier*cv Ouma*	*Panicum maximum*
4	5	61.1gh	146.4e	71.1gh
	10	74.2gh	91.3f	75.6h
	15	59.6h	143.5e	91.8f
8	5	91.2f	224.7c	145.6e
	10	104.1f	237.3c	146.8e
	15	99.3f	238.8c	142.3e
12	5	136.2e	304.4a	184.3d
	10	136.6e	306.1a	196.5d
	15	135.0e	288.8b	191.6d
DMRT 0.05 = 14.1, CV% = 5.6				

Means marked by different letters are significantly different at $p \leq 0.05$ significance level

Table 11 Interaction between frequency of harvest, defoliation height and species on plant height at Alupe in June 2013

Frequency of harvest (weeks)	Defoliation Height (cm)	Plant height (cm)		
		Species		
		Tripsacum laxum	Napier *cv Ouma*	*Panicum maximum*
4	5	58.6k	114.8h	92.2ij
	10	58.3k	164.1e	99.8ij
	15	60.1k	129.7g	97.1ij
8	5	85.9j	189.9cd	144.0f
	10	103.0hi	201.8c	150.2f
	15	91.6ij	195.5c	150.4f
12	5	96.6ij	238.0b	178.1d
	10	95.3ij	262.1a	189.5cd
	15	97.5ij	240.5b	201.9c
$DMRT_{0.05}$ = 12.2, CV% =5.3				

Means marked by different letters are significantly different at p≤0.05 significance level

c) Number of tillers per stool

The ANOVA results in October, February and June, revealed significant interaction (p≤0.05) between frequency of harvest , forage species and defoliation height on tillers that regenerated per stool (Appendices IX, X and XI respectively) at Kakamega site and Alupe site (Appendix 28, 29 and 30 respectively). Napier *cv Ouma* harvested at 4-weekly interval alongside defoliation heights of 5 cm and 10 cm significantly (p≤0.05) influenced the regeneration of most tillers (32and 31 respectively) at Kakamega site (Table 12). This was also observed at Alupe site, though fewer tillers were regenerated. Thus, Napier *cv Ouma* regenerated most tillers (23) at Alupe and Kakamega site in October, out-competing other species. The ability of Napier *cv Ouma* to regenerate more tillers at 4-weekly interval of harvest alongside defoliation heights of 5 cm and 10 cm over other species and frequencies of harvest is one of the most important factor to high cumulative biomass yield as reported in Tables 4 and 5. Mullahey *et al.*, (1990) also observed that defoliating little bluestem *(Schizachyrium scoparium)* at 7 cm stubble height alongside more frequent harvest during growing season produced the highest number of tillers and buds than a single defoliation. Explanation to increased number of tillers on *Napier cv Ouma* at 4-weekly interval of harvest out-competing other species is related to plant height causing competition for light between the tillers. The increase of plant height with infrequent harvests (8-weekly and 12-weekly interval of harvest) increased the leaf area (Sousa *et al.,* 2011) which reduced the quantity and quality of light that penetrated into the plot of grasses and thereby inhibited the emergence of new tillers (Sbrissia *et al.*, 2010) in addition to causing their mortality.

Among the alternative species, *Panicum maximum* maintained the highest number of tillers in October 2012 when harvested at 4-weekly interval alongside defoliation heights of 5 cm and 10 cm, which showed 27 and 24 tillers respectively (Table 12). At both sites, *Tripsacum laxum* regenerated the fewest number of tillers in October regardless of frequency of harvest and defoliation heights (Tables 12 and 13). In June, however, the number of tillers for Napier *cv Ouma* significantly increased and out-competed other species when harvested at 4-weekly interval at Alupe sites regardless of defoliation heights (Table 13). However, the trend in tillering ability seemed to be on increase from October and February to June regardless of the forage species. The findings in this study is consistent with the results of Onyeonagu and Asiegbu (2013) who found tiller number per meter square for *Panicum maximum* increased with frequent cutting interval. This has been attributed to increased light penetration and soil temperature as suggested by Recee *et al*., (1988) cited in Cuomo *et al*., (1998). In the current study, even though tillering ability increased with frequency of harvest alongside defoliation height of 10 cm, it was observed that forage growth vigor decreased. This result suggests that as the frequency of harvest increased, tillering ability increased too.

Among the alternative forages, *Panicum maximum* regenerated the largest number of tillers (80.9) when harvested at 4-weekly interval alongside defoliation height of 10 cm in the month of June at Alupe site (Table 13). This could be attributed to the wet season as suggested by Onyeonagu and Asiegbu (2013) who also observed that re-growth of blue-grama (*Bouteloua gracilis)* from active shoot apices preceded rapidly after cutting when soil water was adequate. Related results were observed at Alupe site in the month of February for *Panicum maximum* but moderately lower tillers (75.1) were observed than in the months of June when harvested at 4-weekly interval of harvest alongside defoliation heights of 10 cm (Table 13). Mullahey *et al.,* (1990) also found that tillering ability in *Phalariscv sirolan* increased progressively as the cutting interval increased from 12 to 2 weeks. The general trend in the tillering ability in the current study showed that 4-weekly interval of harvest influenced more tillering ability than other frequencies of harvest regardless of the species and defoliation heights, while the lowest tiller regeneration was influenced by 12-weekly interval of harvest.

Table 12 Interaction between frequency of harvest, defoliation height and species on number of tillers per stool at Kakamega site in October, 2012

Frequency of harvest (weeks)	Defoliation height (cm)	Number of tillers per stool Species		
		Tripsacum laxum	Napier*cv Ouma*	*Panicum maximum*
4	5	9.9ij	31.5a	27.3b
	10	10.1ij	31.1a	24.2bc
	15	8.4ijk	27.3b	22.7cd
8	5	6.6jkl	21.4cde	23.6bcd
	10	5.1kl	15.6gh	19.6defg
	15	5.8kl	24.0bc	19.7defg
12	5	2.9l	17.5efg	20.4cdef
	10	3.6l	12.3hi	18.3efg
	15	4.2l	18.0efg	17.1fg
$DMRT_{0.05}$ = 3.6, CV% =13.2				

Means marked by different letters are significantly different at p≤0.05 significance level

Table 13 Interaction between frequency of harvest and species on number of tillers per stool at Alupe site

Season	Frequency of harvest (weeks)	Number of tillers Species		
		Tripsacum laxum	Napier *cv Ouma*	*Panicum maximum*
October 2012	4	6.76f	23.2ab	23.6a
	8	3.37g	16.4e	21.1c
	12	6.2f	21.9bc	19.0d
$DMRT_{0.05}$ = 1.58, CV% = 10.51				
June 2013	4	18.8d	86.1a	80.9a
	8	13.3e	28.1c	50.8b
	12	8.43e	24.3c	46.8b
$DMRT_{0.05}$ = 5.3, CV% = 13.9				

Means marked by different letters are significantly different at p≤0.05 significance level

Table 14 Interaction between frequency of harvest, defoliation heights and species on number of tillers per stool at Alupe site in February 2012

Frequency of harvest (weeks)	Defoliation height (cm)	Number of tillers Species		
		Tripsacum laxum	Napier*cv Ouma*	*Panicum maximum*
4	5	10.7lm	98.9b	66.7d
	10	11.3l	115.3a	75.1c
	15	9.4lmn	97.2b	59.3e
8	5	8.9lmn	31.5ghi	30.8hi
	10	8.9lmn	25.8j	33.9gh
	15	10.7lm	25.7j	32.2ghi
12	5	7.6mn	34.3g	38.7f
	10	8.0lmn	22.2k	32.0ghi
	15	6.6n	23.6jk	29.9i
$DMRT_{0.05}$ = 3.1, CV% = 5.2				

Means marked by different letters are significantly different at $p \leq 0.05$ significance level

d) Leaf blade length per tiller

ANOVA results in October, February and June showed significant ($p \leq 0.05$) interaction between frequency of harvest and forage species on leaf length per tiller regardless of defoliation height at Kakamega site (Appendix XII, XIII and XIV respectively) and Alupe sites (Appendix 31, 32 and 33 respectively). No significant effect ($p \leq 0.05$) was observed between frequencies of harvest on leaf length for Napier grass *cv Ouma* in October at Alupe site (Table 15). This could be explained by initial availability of nitrogen in the soil that stimulated the growth of leaves regardless of the frequencies of harvest. However in subsequent months, significant influence ($p \leq 0.05$) was observed between frequencies of harvest on leaf length for Napier grass *cv Ouma* and alternative grasses regardless of defoliation height in October at both sites (Tables 15 and 16). Similar trends were observed in the subsequent periods of harvest. Napier grass *cv Ouma* and *Tripsacum laxum* maintained relatively the same leaf lengths compared *to Panicum maximum* regardless of frequencies of harvest and defoliation heights across the study sites and months of harvest *(*Table 19 and 20). Morphologically, the leaf length for *Tripsacum laxum* and Napier *cv Ouma* are longer than *Panicum maximum* (Cook et al., 2005). This was demonstrated in the current study regardless of frequency of harvest alongside defoliation heights. However, among the alternative forage species, *Tripsacum laxum*, showed longest leaf size across the seasons (October 80.6 cm, February 77.5 cm, and June 96.7 cm) when harvested at 8-weekly interval regardless of defoliation heights at Alupe site (Table 14) and similar trends were observed at Kakamega site (Table 20).

Table 15 Interaction between frequency of harvest and species on leaf blade length per tiller at Alupe

Season	Frequency of harvest (weeks)	Leaf blade length (cm) Species		
		Tripsacum laxum	Napier *cv Ouma*	*Panicum maximum*
October 2012	4	52.4b	81.7a	25.9d
	8	80.6a	83.3a	34.6c
	12	54.7b	84.0a	33.5c
$DMRT_{0.05}$ = 5.03, CV% = 8.9				
February 2013	4	63.3c	77.3b	22.7e
	8	77.5b	86.0a	36.8d
	12	66.9ec	85.7a	31.6d
$DMRT_{0.05}$ =6.33, CV=10.9				
June 2013	4	56.3d	72.8c	25.4f
	8	96.7a	91.9a	33.0e
	12	81.6b	78.6b	32.5e
$DMRT_{0.05}$ = 5.63, CV%= 9.				

Means marked by different letters are significantly different at $p \leq 0.05$ significance level

Table 16 Interaction between frequency of harvest and species on leaf blade length per tiller at Kakamega

Season	Frequency of harvest (weeks)	Leaf length (cm) Species		
		Tripsacum laxum	Napier *cv Ouma*	*Panicum maximum*
October 2012	4	63.4d	67.5c	31.2i
	8	58.1e	79.6a	39.4g
	12	56.2f	73.3b	37.9h
$DMRT_{0.05}$ = 0.5, CV% =8.0				
February 2013	4	64.4c	75.1a	34.0d
	8	68.8bc	78.0a	38.6d
	12	67.8bc	73.5ab	27.5e
$DMRT_{0.05}$ = 5.6, CV% = 10.0				
June 2013	4	84.1c	87.6c	37.0f
	8	87.5c	118.4a	45.6f
	12	61.3d	105.7b	30.5g
$DMRT_{0.05}$ = 6.3, MSE = 43.2, CV% = 9.0				

Means marked by different letters are significantly different at p≤0.05 significance level

e) Basal diameter per stool

ANOVA results in October, 2012 showed significant (p≤0.05) interaction between frequency of harvest, defoliation height and forage species on basal diameter per stool at Kakamega site (Appendix XV). However, in February and June, the ANOVA results revealed a significant (p≤0.05) interaction between frequency of harvest and species on basal stool diameter (Appendix XVI and XVII At Alupe site however, the ANOVA results showed a significant (p≤0.05) interaction effect between frequency of harvest and species on basal diameter in the months of October, February and June (Appendix XXXIII, XXXIV and XXXV respectively). Harvesting of Napier grass *cv Ouma* at 8-

weekly interval alongside defoliation height of 10 cm significantly ($p \leq 0.05$) increased basal diameter relative to 4-weekly and 12-weekly interval of harvest and over other species in the month of October at Kakamega site (Table 17). As a consequence, 44.0 cm of basal diameter was attained when Napier *cv Ouma* was harvested at 8-weekly interval alongside defoliation height 10 cm. The trend was similar in the subsequent months (February and June) at Alupe site, where Napier *cv Ouma* significantly out-competed other species and frequencies of harvest in basal diameter when defoliated at 8-weekly interval regardless of defoliation heights (Table 18). Among the alternative fodder species, *Panicum maximum* showed significant ($p \leq 0.05$) effect between 4-weekly interval of harvest regardless of defoliation height and other harvest intervals on basal diameter in the month of October (Table 18). The basal diameter for this alternative fodder species ranged from 11.2 cm to 14.0 cm when harvested at 8-weekly and 12-weekly intervals, which out-competed alternative species harvested at 4-weekly intervals regardless of defoliation heights in the month of October (Table 17). The trend was similar in the subsequent months and sites (Table 18). This could be related to the tillering ability which increased with the size of the stool. The current study result is consistent with the findings of Ishaque and Burkhsh *et al*., (2010) who observed that stool diameter of *Cenchrus ciliaris* and *Panicum maximum* increased with the number of tillers and frequent harvest of the plants.

Table 17 Interaction between frequency of harvest, defoliation height and species on stool diameter at Kakamega in October

Frequency of harvest (weeks)	Defoliation height (cm)	Stool diameter (cm) Species		
		Tripsacum laxum	Napier *cv Ouma*	*Panicum maximum*
4	5	4.7l	12.1fg	7.6ijk
	10	5.3kl	15.8de	8.8hij
	15	5.1kl	12.8f	8.2ij
8	5	8.3ij	39.0b	13.0f
	10	9.7ghi	44.0a	13.5ef
	15	7.2ijk	41.5b	14.0ef
12	5	7.4ijk	17.9d	13.1ef
	10	6.3jkl	20.7c	11.3fgh
	15	6.6jkl	21.2c	11.2fgh
$DMRT_{0.05}$ = 2.48, CV% = 10.48				

Means marked by different letters are significantly different at p≤0.05 significance level

Table 18 Interaction between frequency of harvest and species on stool diameter at Alupe

Season	Frequency of harvest (weeks)	Stool diameter (cm) Species		
		Tripsacum laxum	Napier *cv Ouma*	*Panicum maximum*
October	4	5.6g	24.3a	13.6cd
	8	12.0de	16.9b	10.9ef
	12	5.6g	14.5c	9.6f
$DMRT_{0.05}$ = 2.36, CV%=17.34				
February	4	6.1f	16.7d	11.4e
	8	15.9d	30.7a	22.7b
	12	10.3e	19.9c	12.0e
$DMRT_{0.05}$ = 2.36, CV% = 15.28				
June	4	15.0e	28.6b	17.0de
	8	15.7e	36.4a	23.2c
	12	15.3e	29.8b	18.7d
$DMRT_{0.05}$ = 2.67, CV% = 12.79				

Means marked by different letters are significantly different at p≤0.05 significance level

f) Leaf numbers per tiller

In October 2012 and February 2013, interaction between frequency of harvest and forage species showed significant effects ($p \leq 0.05$) on the number of leaves developed per tiller (Appendix 19 and 20 respectively) at Kakamega site. Similar trend of interaction was observed at Alupe in the months of October, February and June (Appendix XXXVI, XXXVII and XXXVIII respectively). However, interaction between frequency of harvest, defoliation heights and species significantly affected the leaf numbers in the month of June at Kakamega site (Appendix XIX). The influence of 8-weekly interval of harvest on development of leaves on Napier *cv Ouma* was significantly greater ($p \leq 0.05$) than other species and frequencies of harvests in the month of October and February at Kakamega site (Table 19). Thus, similar number of leaves (10) was attained for Napier *cv Ouma* in October and February when harvested at 8-weekly interval regardless of defoliation height (Table 19). Similar trend was also observed in the subsequent month of June, nevertheless a low frequency of harvest (12-weekly interval) alongside defoliation height of 5 cm responded over other frequencies of harvest and forage species (Table 20). In the 12-weekly interval of harvest alongside defoliation height of 5 cm, Napier *cv Ouma* significantly ($p \leq 0.05$) increased the number of leaves per tiller (14.5) and therefore out-numbered other species regardless of defoliation heights in the month of June at Kakamega site (Table 20). Among the alternative species, *Tripsacum laxum* grass significantly ($p \leq 0.05$) out-numbered *Panicum maximum* when harvested at 8-weekly and 12-weekly interval relative to other frequencies regardless of defoliation height at Kakamega site in October (Table19). Thus, *Tripsacum laxum* developed 7.3 and 7 leaves in response to 8-weekly and 12-weekly intervals of harvest respectively, significantly lower than *Panicum maximum* regardless of frequencies of harvest and defoliation heights (Table 19).

Table 19 Interaction between frequency of harvest and species on leaf numbers per tiller at Kakamega site

Season	Frequency of harvest (weeks)	Leaf numbers per tiller Species		
		Tripsacum laxum	Napier *cv Ouma*	*Panicum maximum*
October 2012	4	6.4c	6.5c	3.3d
	8	7.3b	10.4a	3.4d
	12	7bc	6.4c	2.0e
$DMRT_{0.05}$ = 0.61, CV% =10.79				
February 2013	4	6.1d	6.6d	3.0f
	8	8.0b	10.0a	3.8e
	12	7.3c	9.5a	2.1g
$DMRT_{0.05}$ = 0.68, CV% =5.21				

Means marked by different letters are significantly different at p≤0.05 significance level

Table 20 Interaction between frequency of harvest, defoliation heights and species interaction on leaf numbers per tiller at Kakamega in June 2013

Frequency of harvest (weeks)	Defoliation heights (cm)	Leaf numbers per tiller Species		
		Tripsacum laxum	Napier *cv Ouma*	*Panicum maximum*
4	5	5.8i	8.0efg	3.2klm
	10	6.2hi	8.8e	3.5jkl
	15	6.2hi	8.2efg	3.3klm
8	5	8.1efg	12.3bc	4.4j
	10	8.4ef	11.1d	4.1jk
	15	7.6fg	11.3cd	4.3jk
12	5	6.3hi	14.5a	2.2m
	10	7.2gh	12.6b	2.4lm
	15	7.5fg	11.4cd	2.3m
DMRT 0.05 = 0.98, CV% = 8.40				

Means marked by different letters are significantly different at p≤0.05 significance level

3.8 Conclusion

1. Dry matter yield for Napier cv *Ouma* was higher than the two alternative fodder species regardless of frequencies of harvest and defoliation heights.
2. The dry matter yield for *Panicum maximum* was highest among alternative species at 4 weeks of harvest alongside basal defoliation height of 10cm.
3. A 4-weekly interval of harvest alongside defoliation height of 10 cm yielded the highest DM across the sites irrespective of fodder species
4. Tillering ability was highest at 4-weeks of harvest regardless of the cultivar and defoliation height across the sites
5. Number of leaves per tiller was specific to the cultivar but in all cases reached peak at 8-weeks of harvest
6. Plant height peaked at 8 to 12 weeks of harvest regardless of defoliation height

CHAPTER FOUR

INFLUENCE OF DEFOLIATION INTENSITY AND FREQUENCY OF HARVEST ON THE NUTRIENT CONTENT OF SELECTED FODDER GRASSES

4.1 Abstract

Samples of selected alternative fodder grasses (*Panicum maximum* and *Tripsacum laxum*) and a Napier grass *cv Ouma* from field experiment were analyzed using Near-Infra-red spectroscopy with the purpose of establishing nutrient content in relation to frequency of harvest, defoliation height and plant parts (stem and leaf). Study design and treatment was as described in chapter 3 section 3.4.2 of this thesis and were analysed using the statsistical Analysis System. The results revealed that *Tripsacum laxum* had the highest concentration of Crude Protein, which ranged from 9.22% to 8.88% on dry matter basis at both study sites regardless of frequency of harvest, defoliation height and plant fraction. The concentration of Total Digestible Nutrient (TDN) in *Tripsacum laxum* was higher than other two species regardless of frequency of harvest, defoliation height and plant fraction. However, the concentration of ADF in *Tripsacum laxum* was the lowest (44.23%) compared to other species regardless of defoliation height and frequency of harvest. The level of minerals in the three fodder species was within the acceptable critical levels for dairy animals regardless of frequency of harvest alongside defoliation heights and plant fractions. The concentration of Phosphorus ranged from 0.17% to 0.28% while calcium ranged between 0.77% to 0.85% and magnesium ranged from 0.37 to 0.48%. The influence of 4-weekly interval of harvest on the CP concentration was highest at Kakamega and Alupe (10.8% and 10.08% respectively) regardless of species and defoliation heights and was attributed to maturity stage of the fodder. Longer intervals of harvest similar to 8 and 12 weeks reduced the quality of forage by having higher concentration of ADF and NDF. The concentration of CP in leaf fraction was higher (ranged from 8.8% to 10.39%) than in stem fraction across the study sites regardless of species, frequency of harvest and defoliation heights. Similarly, the leaf part showed the highest level of TDN and lowest level of ADF and NDF, making the leaves more nutritious than the stems. The level of mineral concentration in leaf and stem part ranged from 0.21% to0.27% and 0.18% to 0.24% respectively at both sites regardless of species, frequency of harvest and defoliation height. This is within the acceptable critical level for lactating cows. The study has showed that *Tripsacum laxum* has higher quality in terms of Crude protein when harvested at 4-weekly interval alongside defoliation height of 10 cm than other species and frequency of harvest. Also forages harvested at 4-weekly interval appeared more superior in quality than those harvested at 8 and 12-weekly intervals due to less fibre content and high protein concentration in the former than later. The study recommends that farmers should combine *Panicum maximum* and *Tripsacum laxum* as alternative forage and should be harvested at intervals of 4 weeks alongside basal defoliation height of 10 cm in Western Kenya.

4.2 Introduction

Poor nutrition is one of the major constraints to livestock productivity in sub-Saharan Africa (Osuji *et al.*, 1993) and it results in low rates of production (Getu *et al.*, 2012). This is because animals thrive predominantly on high fibre feeds which are deficient in essential nutrients for microbial fermentation (Gezahagn *et al.*, 2014). Several factors influence the nutritive value of forages (Ball *et al.* 2001) and their degree of interrelated may vary considerably from one area to another (Waziri 2013). Research recognizes the most appropriate way of dealing with this interrelation factors is to study individual factor while holding others constant as possible. These factors include stage of maturity, edaphic influences, plant species and climate (Osuji *et al.*, 1993).

Palatable and nutritious forages are essential in providing nutrients to grazing livestock in extensive and low-input situations. Mineral deficiencies may depress herbage intake and ultimately decrease livestock production. Grusak and Dellapnna, (1992) observed that mineral concentration vary significantly among forage species ranging from toxic to inadequate for livestock production.

The nutrient content of any forage depends on level of energy in form of carbohydrates, which make up 60% to 80% of the dry matter (Waziri, 2013). In chemical analysis, carbohydrates are arbitrarily grouped into crude fibre and nitrogen free extract (NRC, 1984). The amount of digestible protein produced by the plant depends on the plant species and the class of the animal using the plant (Ball *et al.*, 2001). Minerals are essential for proper functioning of the body process. Apart from sodium, Calcium and

Phosphorus, most essential elements are available in most forage unless these plants grow in areas which experience mineral deficiency (Holecheck *et al*., 1998). Several factors influence the nutritive value of forages (Ball *et al.*, 2001). The degree to which they are interrelated may vary considerably from one area to another (Waziri, 2013). Research recognizes the most appropriate way of dealing with these interrelation factors, thus study individual factor while holding others constant as possible. These factors include stage of maturity, edaphic influences, plant species and climate (Osuji *et al.*, 1993).

4.3 The stage of maturity

The stage of maturity is one of the most important factors that affect chemical composition and digestibility of forages (Saddul *et al.,* 2004). In general, all forages are highly succulent in early growth stages enhancing their palatability (Saddul *et al.*, 2004). In addition, high protein content in relation to low fibre content is exhibited at early growth stage and increases their nutrient concentration (Holecheck *et al*., 1998). The trend in crude fibre content with regard to stage of maturity is normally the reverse for protein (Saddul *et al.,* 2004). As the percentage of crude fibre increases, digestibility usually decreases because crude fibre is resistant to decomposition and often envelopes digestible nutrients rendering them unavailable.

Phosphorus content normally parallels that of protein with regard to seasonal changes. Phosphorus and magnesium decrease significantly with advancing age (Kilcher, 1981). Calcium on the other hand increases with the age of the plant. This is explained on the basis of the increased amount of cellular materials which compose principally of this element. Rauzi *et al*., (1969) suggested that the maturity of the plant increase in calcium and ash is attributed to dust accumulation.

4.4 Edaphic factors

Physical and chemical properties of the soil exert almost unlimited influence on the nutrient content of the plants (Cameron, 2001). Cameron, (2001) observed mineral composition within a forage species and found that soil fertility determines the mineral concentration in fodder species. Thus, plants grown on soils with certain nutrients tend to be rich in these nutrients. Physical properties such as texture and porosity affect the nutritive quality of forage more or less directly. Poorly aerated soils greatly limit the absorption of essential elements specially phosphorus (Cameron, 2001).

4.5 Climatic factors

Climatic factors such as temperatures, humidity, precipitation, light intensity and altitude contribute significantly to nutritive value of forages (Kilcher, 1981). These factors affect respirations, assimilation, photosynthesis and metabolism of forages to an extent that mineral and organic matter is strongly modified even though grown in the same soil. Precipitation may have direct and indirect influence on forage quality through increase of nitrogen, phosphorus and ether extract (Cameron 2001). McCown and Mclean, (1983) reported that insufficient moisture in the soil results to decreased phosphorus and protein contents but increase calcium and crude fibre content. Temperature is the most important factor affecting phenology of plants as low temperature tends to initiate the transformation of starches into plant sugars which are used in plant metabolism.

Since the health of livestock depends on the nutritional value of available forage, it therefore becomes necessary for livestock farmers to understand the nutritional dynamics of forage to sustain adequate growth and reproduction of animals (Osuji *et al.*, 1993). However, more emphasis in research has concentrated on floristic characteristic, palatability, and productivity of alternative fodder grasses but less effort has been spent on assessment of nutritional status of fodder species. Herbage yield in combination with other characteristics like interval of grazing, maturity, proportion of morphological fractions and nutritive value of the herbage yield are useful consideration in the selecting the best variety for forage production. In Western Kenya, scanty information exists on nutrient and mineral concentrations as influenced by three levels of defoliation heights, frequency of harvest and species.

4.6 Objective of the study

To determine the nutrient level in leaf and stem of the fodder species (Napier *cv Ouma*, *Panicum maximum* and T*ripsacum laxum*) harvested at different frequencies and defoliation heights

4.7 Materials and methods

The detail design of this study is as described earlier in chapter 3 section 3.4.2.

4.7.1 Sample preparation and nutrient analysis

After determination of morphological parameters, three internal stools of Napier *cv Ouma* and nine internal stools of *Panicum maximum* and *Tripsacum laxum* were hand-clipped at their respective frequencies of harvest alongside defoliation heights. Leaves and stems were separated manually from the clipped samples, which were subsequently chopped into small pieces (about 3 cm lengths) weighing about 500g. The samples were oven dried at 60^0C for 48 hours to determine percentage dry matter. Dried samples were ground in a Wiley mill to pass through a 1-mm screen for the assessment of nutritive and mineral composition based on percentage dry matter. However, each forage species samples from the three replicates harvested at a specified defoliation height and frequency were composited into single sample. For instance Napier grass *cv Ouma* harvested at 4-weekly interval alongside defoliation height of 5 cm in the three replicates was collapsed into one sample. The samples were taken to KALRO Naivasha for nutrient and mineral analysis. Before scanning, the samples were dried at 60^0C overnight in an oven to standardize the moisture and 3 g of each sample was scanned by Near Infrared (NIR) spectroscopy with an 8nm step. This is one of the recent techniques that uses a source of producing light of known wavelength pattern (usually 800 – 2500 nm) and enables to obtain a complete picture of the organic and inorganic composition of the analyzed substances (Jafari *et al.*, 2003, Van Kampen, 2001). It is now recognized as a valuable tool in the accurate determination of the chemical composition and other nutrient parameters (Givens et al 1997). The samples were analyzed for crude protein, Acid Detergent Fibre and Neutral Detergent Fibre, Total Digestible Nutrients and minerals (Phosphorus, Calcium, Potassium and Magnesium.

4.7.2 Statistical model

$Y_{ijklm} = \mu + S_i + f_j + Sf_{ij} + h_k + Sh_{ik} + fh_{jk} + Sfh_{ijk} + p_l + Sp_{il} + fp_{jl} + hp_{kl} + sfp_{ijl} + shp_{ikl} + Y_{ijklm}$

Where:

- µ - fixed general effects (population mean)
- S_i – Effect of species

- f_j – Effect of frequeancy of harvest
- Sf_{ij} – Interaction effect of species and frequency of harvest
- h_k –Effect of defoliation height
- Sh_{ik} - Interaction effect of secies and defoliation height
- fh_{jk} –Interaction between frequency of harvest and defoliation height
- Sfh_{ijk} – Interaction between species, frequency of harvest and defoliation height
- p_l – Effect of part of plant
- Sp_{il} – Interaction between species and part of plant
- fp_{jl} – Interaction between frequency of harvest and part of the plant
- hp_{kl} – Interaction between defoliation height and part of the plant
- sfp_{ijl} - Interaction between species, frequency of harvest and part of the plant
- shp_{ik} - Interaction between species, defoliation height and part of the plant
- Y_{ijklm} – Experimental error

4.7.3 Statistical analysis

Statistical analysis was done using the Statistical Analysis System (SAS). Differences among the treatments were tested by analysis of variance (ANOVA) and compared using Duncan's Multiple Range Test at 5% significance level as described by Steel and Torrie, (1980).

4.8 Results and Discussions

4.8.1 Effect of fodder species, frequency of harvest, defoliation height and their interaction on nutrient and mineral elements in grass species

a) Effect of fodder species on nutrient and mineral composition

Forage species differed significantly ($p \leq 0.05$) in nutrient and mineral concentration regardless of defoliation heights, frequency of harvest and plant fractions at Kakamega and Alupe sites (Table 21 and 22 respectively). Crude protein concentration in *Tripsacum laxum* was significantly ($p \leq 0.05$) higher than in *Panicum maximum* and Napier *cv Ouma* regardless of frequency of harvest and defoliation heights (Table 22). Thus, species influenced significantly the concentration level of CP than the effect of interaction between frequency of harvest, defoliation height and species (Appendix XXXIX). The concentration of CP in *Tripsacum laxum* was 9.2% while in *Panicum maximum* and Napier *cv Ouma was 6.8% and 7.3% respectively* at Kakamega site, while at Alupe site, the CP concentration in *Tripsacum laxum* differed significantly ($p \leq 0.05$) with other species (Table 21 and 22). Mtengeti *et al.,* (2006) reported slightly low levels of CP concentration in *Tripsacum laxum* (8.9%) and high levels of CP in Napier grass (10.62%) regardless of the frequency of harvest and defoliation height. Gezahagn *et al.,* (2014) noted that protein is the limiting nutrient for grazing animal productivity, a deficiency being manifested in poor overall production by the animal such as low live weight gain, poor reproduction rate and low forage hay intake owing to inability to provide enough nitrogen for microbes in the rumen to break down cellulose. The CP content of all forage grasses and legumes are highly varied with genetic factor, environmental factor and interaction of both and the dilution of CP is increased with increasing plant age (Gezahagn *et al.*, 2014).

The concentration level of ADF and NDF in *Panicum maximum* differed significantly ($p \leq 0.05$) with other species regardless of frequency of harvest and defoliation heights at both sites, with *Panicum maximum* showing the highest concentration of ADF and NDF (48.3% and 76.0% respectively) at Kakamega site and 50.2% and 77.6% respectively at Alupe site (Table 21 and 22). The fibre content of a feed is particularly important for determining quality within the parameter of digestibility (Gezahagn *et al.* 2014). According to Carpici, (2011) forage species differ in ADF concentration and also due to season of harvest. Although preference in the quality of feeds is in most cases placed on high levels of CP and TDN, the ADF in animal feed is required since it is an indicator of forage digestibility and fibre is needed by dairy animals to maintain butterfat test (Carpici 2011). Ayan *et al.* (2010) demonstrated the importance of NDF in determining the quality of forage as a measure of the cell wall content of forages and limits total feed intake in abundant forage diet. The result in the current study is in line with the observation of Ayan *et al.* (2010) that NDF content of pastures was affected by the forage species.

TDN concentration in forage species corresponded with results for CP concentration. Thus, TDN concentration in *Tripsacum laxum* was significantly higher than in *Panicum maximum* and Napier *cv Ouma* at both sites. At Kakamega and Alupe sites, the TDN concentration in *Tripsacum laxum* was 53.1% and 55.2% respectively higher than the available concentration in *Panicum maximum* and Napier *cv Ouma* at both sites (Table 25 and 26). A forage species high in TDN implies digestible components such as protein, carbohydrates and fat are also in high proportion and therefore is nutritious for livestock feeding (Gimenez 1994). The forage species influenced significantly ($p \leq 0.05$) mineral concentration regardless of frequency of harvest alongside defoliation heights across the sites (Table 25 and 26). The concentration of phosphorus in *Tripsacum laxum* was significantly different ($p \leq 0.05$) from *Panicum maximum* and Napier *cv Ouma* at Kakamega site. Similar results were showed for tested grasses at Alupe site, which remained significantly the same (Table 25 and 26).

The level of phosphorus concentration in *Tripsacum laxum* was higher (0.28%) than in other species at Kakamega site. However, phosphorus concentration in the three fodder species was not significantly different ($p<0.05$) at Alupe site by ranging from 0.17% to 0.21% (Table 22). The critical level of phosphorus in feeds for growing and lactating cow ranges from 0.1% to 0.2% (Cameron, 2001). Hence there was no deficiency of phosphorus concentration in tested forages suggesting that feeding dairy animals on these species will not suffer from phosphorus deficiencies and therefore no supplementation is needed.

Calcium concentration was not significantly different in the three fodder species at Kakamega site as it ranged from 0.77% to 0.85%. However, the same mineral was significantly higher in *Tripsacum laxum* (1.25%) than in *Panicum maximum* (1.1%) and Napier *cv Ouma* (1.1%) at Alupe site (Table 22). The critical level of calcium in the feeds for growing and lactating cattle is 0.19% and 0.24% respectively (Cameron, 2001). The calcium content for the three species in this study at both sites ranged from 0.77% to 1.25%, which is far beyond the minimal level required by cattle. The variation of calcium concentration in forages investigated in this study agreed with the findings of Khan *et al.*, (2006) who found that calcium concentration varied greatly and the sources of variation to include the type of forage, portion of the plant fed to animals and the stage of forage maturity. In addition calcium requirements are also influenced by animal factors such as age, weight and type and level of production. Young animals absorb calcium more efficiently than older animals but they have higher requirement because of higher rate of growth (Ndebele *et al*., 2005).

Potassium concentration was significantly ($p<0.05$) higher in *Tripsacum laxum* than other species at both sites. Thus, the level of potassium concentration in *Tripsacum laxum* were 3.3% and 0.8% at Kakamega and Alupe sites respectively compared to the same element in *Panicum maximum* and Napier *cv Ouma*, which was 2.3% and 2.9% respectively at Kakamega site and 0.5% and 0.9% respectively at Alupe site (Table 21 and 22). This level fits in the critical level of potassium in feeds required by dairy animals, which ranges between 0.5 to 0.8% of dry matter though may increase when the animal is under stress (Anonymous, 2005). Cameron, (2001) reported 4-5% of potassium in young growing forage while mature forages contained as low as 0.4-0.5%. Thus, potassium deficiency may arise in delayed frequency of harvesting or grazing forages (Khan *et al.*, 2010b). High forage diets typically contain several times the amount of potassium present in high grain diets. Since potassium is not readily stored in animals, it must be supplied daily in the diet (Khan *et al.*, 2010).

The concentration level of magnesium was significantly ($p<0.05$) higher in Napier *cv Ouma* than *Panicum maximum* and *Tripsicum laxum* at both sites. The concentration of magnesium in Napier *cv Ouma* was 0.34% compared to the same element in *Panicum maximum* and *Tripsicum laxum,* which was 0.29% and 0.31% respectively at Kakamega site and 0.37% and 0.41% respectively at Alupe site (Table 21 and 22). The mean Magnesium levels recorded in the three fodder species regardless of the frequency of harvest and defoliation height in the current study were adequate for livestock as earlier reported in different studies (Khan *et al.,* 2010a). Cameron, (2001) recommended the critical levels of Mg in feeds for the growing and lactating cattle as 0.19%. The three forages in the current study contained more than sufficient Mg levels required amounts by dairy animals and therefore animals fed on these forages will not require supplementation of this element. Thus, the animals will not suffer from low blood Mg during lactation which causes low milk yield (Nouman 2014).

It should however be noted that all mineral nutrients including magnesium, phosphorus, calcium and potassium can have hazardous effects on ruminants if included in the dietary sources at very high levels. Theoretically, there is a series of required levels and also of tolerance levels of each element which will vary from animal-to-animal (Khan *et al.,* 2010).

Table 21 Effect of fodder species on nutrient and mineral value at Kakamega site

Species	%CP	%ADF	%NDF	%TDN	%P	%Ca	%K	%Mg
Tripsacum laxum	9.2a	44.2b	71.8a	53.1a	0.3a	0.8a	3.3a	0.3b
Panicum maximum	6.8b	48.3a	76.0a	48.6b	0.3b	0.8a	2.3b	0.3ab
Napier	7.3b	45.0b	74.2a	52.3a	0.3ab	0.9a	3.1a	0.3a
DMRT	1.3	2.7	4.6	3.0	0.03	0.1	0.4	0.04
CV%	20.8	14.0	12.0	11.2	19.1	21.4	25.0	26.2

Within a column, means marked by different letters are significantly different at p≤0.05 significance level

CP=Crude protein; ADF=Acid Detergent Fibre; NDF=Neutral Detergent Fibre; TDN=Total Digestible Nutrient; P=Phosphorus; Ca=Calcium; K=Potassium; Mg=Magnesium

Table 22 Effect of fodder species on nutrient and mineral value at Alupe site

Species	%CP	%ADF	%NDF	%TDN	%P	%Ca	%K	%Mg
Tripsacum laxum	8.9a	42.3c	74.2b	55.2a	0.2a	1.3a	0.8a	0.4b
Panicum maximum	5.9b	50.2a	77.6ab	46.4c	0.2a	1.1b	0.5b	0.4b
Napier	6.9b	44.6b	79.9a	52.3b	0.2a	1.1b	0.9a	0.5a
DMRT	1.1	2.1	5.1	2.4	0.0	0.1	0.2	0.1
CV%	28.2	8.6	12.3	0.8	32.6	11.7	59.4	22.4

Within a column, means marked by different letters are significantly different at p≤0.05 significance level

CP=Crude protein; ADF=Acid Detergent Fibre; NDF=Neutral Detergent Fibre; TDN=Total Digestible Nutrient; P=Phosphorus; Ca=Calcium; K=Potassium; Mg=Magnesium

b) Effect of frequency of harvest on nutrient and mineral composition in fodder species

The 4-weekly interval of harvest resulted in significantly (p≤0.05) higher CP content than other frequencies of harvest in all forage species and defoliation heights in both experimental sites (Table 23 and 24). Forage species that were harvested at 4-weekly intervals at Kakamega and Alupe sites contained CP concentration of 10.6% and 10.1% respectively. The CP concentration in forages relative to 8-weekly and 12-weekly interval of harvest was 6.7% and 6.6% respectively at Kakamega site while at Alupe site, was 6.3% and 5.3% respectively. Wendling *et al.* (2008) observed that dry matter yield of Napier grass *cv Ouma* due to delayed harvest was inversely proportion to CP concentration, demonstrating that harvesting forage at longer intervals in grass is not the best strategy to achieve high dairy production levels. In addition, 4-weekly interval of harvest regardless of basal defoliation height and forage species is a phenological stage when plants are still young and leafy and therefore more accumulating most nitrogen in their leaves leading to higher CP concentration than ADF and NDF (Roma *et al.*, 2012).These results agree with the work of Pan (1986) that harvested forage at early stage contain higher CP concentration than at later stage and that forage quality decreased with maturity due to high stem to leaf ratio. It is also noted that as the plant advance in growth, the cell wall becomes more lignified and therefore the fibres content increases as the protein level decreases (Hsu *et al.,* 2005).

The effect of 8-weekly from 12-weekly interval of harvest did not differ significantly for ADF and NDF concentration in the forage regardless of defoliation heights and plant fractions across the study sites (Table 23 and 24). However, the effect of these two frequencies of harvest on concentration of ADF and NDF in forages was significantly ($p \leq 0.05$) different from 4-weekly interval of harvest across the sites. As shown in Table 33 and 34, forages harvested at 8-weekly and 12 weekly intervals had a concentration of 47.0% and 46.8% of ADF respectively at both sites. However, the NDF concentration levels in forages due to the influence of 8-weekly and 12-weekly interval of harvest was 75.3% and 75.8% respectively at Kakamega site while 79.2% and 79.4% was observed at Alupe site. It is important to note that NDF concentration of forage is a dominant factor in determining forage quality (Gezahagn *et al.,* 2014). The NDF contents above 60% in legumes results in decreased voluntary feed intake, feed conversion efficiency and longer rumination time (Shirley 1986; Hoffman *et al*., 2001). This means that the NDF content of all the tested forage species was found to be above the threshold level, which indicates lower digestibility. While supporting the current results Gezahagn *et al.,* (2014), observed that grasses contain higher concentration of NDF and ADF than legumes and this is attributed to higher fibre concentration found in leaf and stem fraction of grasses compared to legumes. Thus, it is necessary to utilize herbage at early growth stage (4-weekly interval of harvest) in order to obtain a high metabolizable energy intake. Minson,

(1990) showed that the decline in digestibility with maturity was more rapid in tropical grasses than legumes, which retained relatively high digestibility at maturity. Values recorded for a number of different tropical grasses indicate that there is a decrease of 0.2% to 0.1% digestibility rate with increasing forage maturity (Milford and Minson, 1966). Zhang *et al.,* (2012) found similar results of infrequent harvest influencing high levels of ADF and NDF in fodder crops, making the plant less digestible and decline in quality. MacDonald et al., (2002) reported that as the frequency of harvest is delayed leads to increased maturity of the plant and therefore increase in the proportion of the fibre in the herbage which has a strong influence on digestibility.

A significant ($p \leq 0.05$) difference was observed between frequencies of harvests on the concentration of TDN in forages regardless of defoliation height and plant fractions at both sites (Table 23 and 24). Forages harvested at 4-weekly intervals showed the highest concentration level of TDN (Kakamega 54.2% and at Alupe 54.6%) compared to forages harvested at 8-weekly and 12-weekly intervals at both sites. The 4 and 8-weekly interval of harvest significantly ($p \leq 0.05$) influenced the concentration levels of phosphorus in forages irrespective of defoliation intensities and parts of the plant harvested at Kakamega and Alupe sites (Table 23 and 24). The highest concentration level of phosphorus was achieved by harvesting forages at 4 and 8-weekly intervals regardless of plant fraction and defoliation heights (Table 27 and 28) at both sites. A concentration level of 0.28% and 0.26% was observed on forages when harvested at 8 and 12-weekly interval respectively at Kakamega site while 0.23% and 0.20% of phosphorus was observed at Alupe site. Similar trend was observed for calcium, potassium and magnesium in forages as a result of frequencies of harvest regardless of defoliation height of harvest and plant fractions at both sites (Table 23 and 24). The highest concentration level of calcium (0.9% and 1.1% at Kakamega and Alupe site respectively) was influenced by harvesting forages at 4-weekly intervals regardless of plant fraction and defoliation heights (Table 23 and 24). While investigating defoliation frequencies on dry matter yield and nutrient content of two *Centrosema* species, Faria-Marmo and Chirinos (2005) established similar results that calcium concentrations increased with frequent interval of harvest and young growth stage. MacDonald et al (2002) reported that mineral concentration in forages declined with delayed grazing and is also influenced by soil nutrient level and season climate. Minson (1990) attributed decline in mineral content to increase in the proportion of the stem fraction as the forage matures since stems generally contain less Calcium than leaves. Similar concentration level of potassium (3%) was observed on forages when harvested at 8-weekly and 12-weekly interval respectively at Kakamega site while 0.8% of phosphorus was observed at Alupe site respectively (Table 23 and 24). The highest concentration level of magnesium (0.3% and 4.9% at Kakamega and Alupe site respectively) was influenced by harvesting forages at 4-weekly intervals regardless of plant fraction and defoliation heights (Table 23 and 24). As the plant matures, mineral content declines due to the natural dilution process and translocation of nutrients to the root system (Ford *et al.,* 1979, Underwood *et al.*1999, Spears 1994).

Table 23 Effect of frequency of harvest on nutrient and mineral value at Kakamega site

Frequency of harvest	%CP	%ADF	%NDF	%TDN	%P	%Ca	%K	%Mg
F4	10.6a	43.2b	70.3b	54.2a	0.28a	0.9a	3.0a	0.3a
F8	6.7b	47.0a	75.3a	49.9b	0.26ab	0.7b	3.0a	0.3b
F12	6.6b	46.8a	75.7a	50.2b	0.24b	0.8ab	2.4b	0.31ab
DMRT	1.3	2.7	4.6	3.0	0.03	0.1	0.4	0.04
CV%	40.8	14	12.0	11.2	19.08	21.4	25.0	26.2

Within a column, means marked by different letters are significantly different at p≤0.05 significance level

CP=Crude protein; ADF=Acid Detergent Fibre; NDF=Neutral Detergent Fibre; TDN=Total Digestible Nutrient; P=Phosphorus; Ca=Calcium; K=Potassium; Mg=Magnesium

Table 24 Effect of frequency of harvest on nutrient value at Alupe site

Frequency of harvest	%CP	%ADF	%NDF	%TDN	%P	%Ca	%K	%Mg
F4	10.1a	42.8b	73.5b	54.6a	0.2a	1.2a	0.8a	0.5a
F8	6.3b	47.0a	79.2a	50.0b	0.2a	1.1b	0.8a	0.4b
F12	5.3b	47.6a	79.4a	50.0b	0.16b	1.1b	0.6b	0.4b
DMRT	1.0	2.1	5.0	2.4	0.03	0..1	0.2	0.1
CV%	28.2	8.6	12.3	0.8	32.57	11.7	59.4	22.4

Within a column, means marked by different letters are significantly different at p≤0.05 significance level

CP=Crude protein; ADF=Acid Detergent Fibre; NDF=Neutral Detergent Fibre; TDN=Total Digestible Nutrient; P=Phosphorus; Ca=Calcium; K=Potassium; Mg=Magnesium

c) Effect of plant parts on nutrient and mineral content in fodder species

The plant parts (Stem and leaf) significantly differed (p≤0.05) in the concentration level of CP regardless of forage species, frequencies of harvest and defoliation heights at each site (Table 25 and 26). Leaf fraction contained the highest concentration of CP at both sites (Kakamega 10.4% and Alupe 8.9%) compared to stem which had a concentration of 4.0% at Kakamega and 4.3% at Alupe site (Table 25 and 26). Norton (1982) reported that CP in leaf is higher than in stem fraction of the plant and that the high fraction of stem and leaf senescence are the major factors that affect CP of biomass during the growth and harvesting stage of the crop. The results presented in the current study are in agreement with the findings of Van Soest *et al.*, (1991) who asserted that nutritive value and forage quality of the forage is a consequence of maturity stage and conditions of the environment under which the crop matures. Jung and Engels, (2002) reported that as stem in forage mature, protein content decreases and carbohydrate content increases and at maturity percentage total fibre increases due to increase in xylem tissues

Similarly, plant fractions differed significantly ($p \leq 0.05$) in the concentration level of ADF and NDF regardless of forages species, frequencies of harvest and defoliation heights across the sites (Table 25 and 26). Stems contained significantly ($p \leq 0.05$) the highest concentration level of ADF (52.2%) and NDF (83.1%) at Kakamega site while 52.1% and 84.3% of ADF and NDF concentrations respectively were observed in stems at Alupe site (Table 25 and 26). In agreement with the current results, Karachi (1997) reported that stems fraction have higher NDF concentration than leaves which is due to higher concentration of fibre and lignin. Significant difference ($p \leq 0.05$) was observed between leaf and stem in relation to TDN concentration levels regardless of frequencies and defoliation heights across the sites. The concentration of TDN in leaves was significantly higher (56.4%) than in stem (44.2%) at Kakamega site and similar trend was observed for the Alupe site (Table 25 and 26). The concentration levels of minerals differed significantly in plant fractions regardless of defoliation frequencies, forage species and defoliation heights across the sites. The concentration level of P, Ca, K and Mg in leaves was significantly higher than in stems across the study sites. The concentration level of P in leaves was 0.27% and 0.2% at Kakamega and Alupe site respectively. This was significantly higher than the concentration of the same elements in the stem (0.24% and 0.18% at Kakamega and Alupe site respectively). Calcium concentration in the leaves was 1% and 1.3% at Kakamega and Alupe sites respectively, which was significantly higher than in the stem at both sites (0.58% and 0.98% at Kakamega and Alupe respectively). Potassium levels in stem and leaf at Kakamega site was not significantly different irrespective of fodder species, defoliation intensity and frequency of harvest. This result was not the same at Alupe site. At Alupe site, Potassium levels in leaf was more (1.0%) than in stem (0.4%).There was a significant difference between leaf and stem in the magnesium content irrespective of fodder species, defoliation intensity and frequency of harvest at both experimental sites (Table 25 and 26). Magnesium level was higher in leaf than in stem at both sites. The level of magnesium in both the leaf and stem was 0.3% at Kakamega site. At Alupe site, the level of magnesium in the leaf and stem was 0.5% and 0.4% respectively.

Wiersma and Bertam, (2007) showed that the digestibility of stem section decreased with increasing maturity while leaves did not. They further observed that the lower stem portions (bottom two thirds) decreased in quality faster pace than did the upper portion of the stem. This occurs because the lower stem section sustained growth for a long period and therefore tends to be more fibrous and woody compared to the less mature upper stem section. Stichler and Bade, (2002) noted that since leaves are more digestible than stems and contain most of the nutrients, then the higher the leaf content the higher the quality.

Table 25 Effect of plant fraction on nutrient value at Kakamega site

Plant fraction	%CP	%ADF	%NDF	%TDN	%P	%Ca	%K	%Mg
Leaf	10.4a	41.2b	67.5b	56.40a	0.3a	1.0a	2.7a	0.3a
Stem	4.1b	52.2a	83.1a	44.2b	0.2b	0.5b	2.9a	0.3b
DMRT	1.1	2.2	3.8	2.4	0.02	0.1	0.3	0.03
CV%	40.8	14	12.0	11.2	19.1	21.4	25.0	26.2

Within a column, means marked by different letters are significantly different at p≤0.05 significance level

Table 26 Effect of plant parts on nutrient value at Alupe site

Plant fraction	%CP	%ADF	%NDF	%TDN	%P	%Ca	%K	%Mg
Leaf	8.9a	41.9b	73.0b	55.5a	0.2a	1.3a	1.0	0.5a
Stem	4.39b	52.1a	84.3a	44.3b	0.2b	1.0	0.4b	0.4b
DMRT	0.9	1.7	4.2	2.0	0.03	0.1	0.12	0.04
CV%	28.2	8.6	12.3	0.8	32.6	11.7	59.4	22.4

Within a column, means marked by different letters are significantly different at p≤0.05 significance level

Conclusion

1. The concentration level of crude Protein was higher in *Tripsacum laxum* than in Napier cv Ouma and *Panicum maximum*, but lower in Acid Detergent Fibre (ADF) regardless of frequency of harvest and defoliation height, and is attributed to leafiness of *Tripsacum laxm.*

2. The concentration level of crude protein was higher at 4-weekly interval of harvests than 8 and 12-weekly intervals regardless of the species, defoliation heights and plant plants

3. The concentration level of crude protein in leaf was higher than in stem at both sites regardless of the species, frequency of harvest and defoliation heights.

4. The concentration level of total digestible nutrient was higher in leaves than stems irrespective of frequency of harvest, defoliation height and species.

5. The concentration level of acid detergent fibre was higher in stems than in leaves irrespective of frequency of harvest, defoliation height and species.

6. Mineral content in the three fodder species was within the recommended levels for dairy animal feeds

CHAPTER FIVE

INFLUENCE OF MOISTURE REGIME AND SOIL FERTILITY ON GROWTH AND DEVELOPMENT OF SELECTED FODDER GRASSES AS ALTERNATIVE TO NAPIER IN WESTERN KENYA

5.1 Abstract

The description of morphological characteristics of plants is based on the canopy diameter, plant height, number of tillers, leaf length, stool diameter, leaf width and leaf numbers. The study investigated the influence of moisture regime and fertilizer level on morphological characteristics of two alternative fodder grasses (*Panicum maximum*Jacq and *Tripsacum laxum)* Scrib and Merr*)* and a Napier grass *cv Ouma*. The experiment was a randomized complete block design with three replicates in a factorial arrangement in relation to three moisture regimes (two, four and six days watering) and two fertilizer levels (recommended rate of 100kg/ha of DAP and control). The trial was conducted in the green house at the University of Eldoret and root split forage species planted in pots filled with parental loam soil. The parameters were measured on weekly basis for a period of 15 weeks after planting. The ANOVA results showed significant differences between species ($p<0.05$), moisture regimes ($p<0.05$) and fertilizer levels ($p<0.05$) on parameters height, canopy diameter, number of tillers, leaf length and leaf width. Napier was the tallest (91cm) and the widest in canopy diameter (63 cm). *Panicum maximum* developed largest number of tillers (19) followed by Napier (16) while *Tripsacum laxum* had the least tillers (12). It is concluded that irrigation of fodder at intervals of two and four days alongside fertilizer application morphologically performed better than at six days interval regardless of fertilizer application. Therefore farmers in western Kenya should apply DAP at recommended rate to promote growth, development and yield of fodder. Where possible, farmers should also irrigate fodder grases at 4-day intervals to increase productivity.

5.2 Introduction

Water and soil nutrients are major abiotic factors that commonly effect plants for higher yield and development (Lambers *et al.*, 1998). Inadequate water at critical stages of plant affects the morphological structures of the plant and productivity (Bahmani, 1999). However, plants may vary in acquisition and efficient use of water depending on the rooting system, leaf numbers, positioning of the stomata and environmental conditions (Lambers *et al.*, 1998). While reviewing the influence of soil moisture in plant growth and seed yield, Muyekho, (1993) observed that plant morphogenesis such as leaf area development, branching, root growth and physiological processes affects reproductive growth. Van Loo, (1992) measured leaf area expansion of perennial ryegrass and observed reduced leaf appearance due to water stress. The total leaf area of a plant however, does not remain constant after all the leaves have matured but some leaves drop due to senescence or physiological adaptation to drought (Lamber *et al.*, 1998).

Physiological relationship exists between plant tolerance to moisture stress and secondary shoot formation (Lambers, 1998). In an experiment comparing corn (*Zea mays*) and Sorghum (*sorghum bicolar*), Lambers, (1998) showed that Sorghum continued to grow and flower after main shoot had fully matured because of secondary shoots. This was unlikely for corn which hardly develops secondary shoots. Water deficiency in stressed plants tends to occur during day time when evapo-transpiration rate is high but rehydrated at night stimulating substantial leaf growth (Taiz and Zeiger, 2002). However, because of changes in sensibility and yield threshold, the growth rate is still lower than that of unstressed plants at the same turgor.

Water stress limits not only the size of individual leaves, but also the number of leaves on a plant, because it decreases both the number and the growth rate of the branches (Lambers *et al.,* 1998). The growth of stems is also affected by the same forces that limit leaf growth during the same stress. In addition, water stress deficit affects the development of root system as the root-shoot relations appear to be governed by a functional balance between water uptake by the root and photosynthesis by the shoot (Lambers *et al.,* 1998). When water uptake is curtailed, leaf expansion is affected very early, but photosynthesis activity is much less affected. Inhibition of leaf expansion reduces the consumption of carbon-dioxide and energy and a greater part of the plant assimilates are distributed to the root system where they can support further growth (Lambers*et al.,* 1998).

Effects of water stress on fodder grass yield are less well understood (but presumably are related to complex structural changes in the cell wall (Lambers *et al.,* 1998). Pasture improvement levels require detailed information on agronomic management practices that are tailored to practical system for the farm and which meets the economic goals of the farmer. The most practical and effective method to increase dry matter yield and quality production in pasture farming is with the use of appropriate and adequate fertilizers (Frame, 1992). Fertilization can increase dry matter yield up to two or three folds in areas with poor soil nutrients and annual rainfall of over 400 mm (Elliot and Abbott, 2003). Nitrogen and Phosphorus are usually the main limiting nutrients to fodder productivity, with potassium being an occasional constraint (Mafongoya *et al.,* 2000). The selection and management of fodder crops for dairy production requires a quantitative and qualitative knowledge of the morphological characteristics of the fodder in relation to biomass yield. Important factors that influence morphological characteristics of the plant are the biotic and abiotic factors (Assuero and Tognettiet, 2010) which should be adequately understood.

5.3 Objective of the study

To establish the influence of moisture regime and fertilizer level on morphological characteristics of selected alternative fodder grasses (*Panicum maximum* and *Tripsacum laxum*) and Napier grass *cv Ouma.*

5.4 Materials and methods

5.4.1 Experimental location climate and soil.

The experiment was carried out at the school of Agriculture, University of Eldoret in a greenhouse under natural daylight from March to June 2013. The temperature was partially regulated and measured within two minimum and maximum thermometers, which showed the mean maximum temperature of 28^0C and the mean minimum temperature of 23^0C. The pH of the soil at the start of the experiment was 5.1% indicating that the soil was moderately acidic (Okalebo et al., 2002. The carbon content of the soil was 3.4% (Table 27) which indicated that the soil was moderately fertile for crop production. This soil was sourced from KALRO Kakamega site.

Table 27 Nutrient analysis of the parental soil

Soil Attributes	Mean
Soil pH (1:2.5 soil: water)	5.1
Organic carbon%	3.4
Nitrogen%	0.2
Olsen P (mg kg^{-1})	7.0
Sand%	72
Clay %	18
Silt%	10
Textural Class	Sandy-loam

5.4.2 Experimental treatments

The treatment consisted of three irrigation frequencies, three species and two fertilizer levels. These three irrigation frequencies were 2-days, 4-days and 6-days interval of irrigation that were randomly distributed within the blocks. The species which were tested included *Panicum maximum*, *Tripsacum laxum* and Napier *cv Ouma*, which were randomly distributed within the blocks. The level of fertilizers tested were no application of fertilizer and application of fertilizer distributed randomly within the blocks. There were 18 treatments replicated three times (Figure 5).

5.4.3 Design and plot layout for greenhouse experiment

A Randomized Complete Bock Design (RCBD) with three replicates of factorial arrangement of treatments (irrigation interval, fertilizer and species) was used. Three moisture levels were imposed by adding water to the soil after two days, four days and six days at field capacities. The two fertilizer levels were F1 = no fertilizer and F2 recommended fertilizer level was applied. The species were *Panicum maximum* grass, *Tripsacum laxum* and Napier*cv Ouma*.

I_2F_1P **T1**	I_2F_0N **T4**	I_4F_1G **T9**	I_4F_0G **T10**	I_6F_0G **T15**	I_6F_1P **T16**	I_2F_1G **T3**	I_2F_0G **T5**	I_4F_0P **T11**	I_4F_1P **T8**	I_6F_0G **T15**	I_6F_0N **T13**	I_2F_1G **T3**	I_2F_1P **T1**	I_4F_0G **T10**	I_4F_1G **T9**	I_6F_0G **T15**	I_6F_1N **T17**
I_2F_1N **T2**	I_2F_0G **T5**	I_4F_1P **T8**	I_4F_0P **T11**	I_6F_0P **T14**	I_6F_1N **T17**	I_2F_0P **T6**	I_2F_0N **T4**	I_4F_0G **T10**	I_4F_0N **T12**	I_6F_1G **T18**	I_6F_0P **T14**	I_2F_1N **T2**	I_2F_0P **T6**	I_4F_0N **T12**	I_4F_1N **T7**	I_6F_0P **T14**	I_6F_1P **T16**
I_2F_1G **T3**	I_2F_0P **T6**	I_4F_1N **T7**	I_4F_0N **T12**	I_6F_0N **T13**	I_6F_1G **T18**	I_2F_1N **T2**	I_2F_1P **T1**	I_4F_1G **T9**	I_4F_1N **T7**	I_6F_1P **T16**	I_6F_1N **T17**	I_2F_0N **T4**	I_2F_0G **T5**	I_4F_1P **T8**	I_4F_0P **T11**	I_6F_1G **T18**	I_6F_0N **T13**

Figure 5. Plot lay out for Green house Experiment (Completely Randomized Block Design in a factorial arrangement) Source: Author 2014

Treatments key

T1 = Panicum irrigated at 2 days interval with fertilizer
T2 = Napier irrigated at 2 days interval with fertilizer
T3 = Guatemala irrigated at 2 days interval with fertilizer
T4 = Napier irrigated at 2 days interval with no fertilizer
T5 = Guatemala irrigated at 2 days interval with no fertilizer
T6 = Panicum irrigated at 2 days interval with no fertilizer
T7 = Napier irrigated at 4 days interval with fertilizer
T8 = Panicum irrigated at 4 days interval with fertilizer
T9 = Guatemala irrigated at 4 days interval with fertilizer
T10 = Panicum irrigated at 4 days interval with no fertilizer
T11 = Guatemala irrigated at 4 days interval with no fertilizer
T12 = Panicum irrigated at 4 days interval with no fertilizer
T13 = Napier irrigated at 6 days interval with no fertilizer
T14 = Panicum irrigated at 6 days interval with no fertilizer
T15 = Guatemala irrigated at 6 days interval with no fertilizer
T16 = Panicum irrigated at 6 days interval with fertilizer
T17 = Napier irrigated at 6 days interval with fertilizer
T18 = Guatemala irrigated at 6 days interval with fertilizer

5.4.4 Establishment of greenhouse experiment

The sample parental sandy loam soil of the three fodder grasses were prepared by digging at the depth of 15 cm deep, targeting the top layer. The soil was hand screened to remove weeds before being transported to the green house at the University of Eldoret. However, prior to filling the soil in 15-litre plastic pots, it was sun dried for a period of three days and sieved through a 0.5 cm screen to further remove weed seeds and other impurities. The soil mineral analysis was carried out to determine mineral composition of the soils (Table 27). One root- split sample of each fodder grasses and Napier *cv Ouma* was uprooted at 15 cm deep **(**Donkor *et al*., 2003) from the parent field at KALRO Kakamega. The root-split sample of each fodder grass was placed carefully into a 30 cm-diameter and 15 cm deep plastic pot with little disturbance as possible. To prevent channeling of water along the outer edge of the soil core after watering, the small space between the edge of the soil and walls of the tin was carefully filled with soils collected from the edges of the holes left by digging the fodder grass. To avoid water logging in the pots, five tiny holes were opened at the bottom of the pots to allow free drainage.

The moisture level treatment was applied by a means of gravimetric method described by (Donkor*et al*., 2003). The moisture content of the soil at field capacity was determined on three replicate samples. The pots were brought to field capacity by standing their bases in water until the waterfront reached the top of the pot. The pots were removed and left to stand on an elevated wire grid to allow draining of water freely through the basal holes. At this water content, the pots were weighed. The figure obtained was the value of moisture content at field capacity that was maintained to provide a required water regime.

The green house was maintained at an air temperature ranging between 23^0C to 28^0C with 18 hour photoperiod (Donkor *et al*., 2003). Morphological and phenological observations were made on weekly period for the two grasses and Napier *cv Ouma* on their response to treatments. Morphological characteristics of the plants were taken as follows: plant height, tillers number and leaf-length leaf-width and canopy diameter. Total root DM of the fodder grasses was measured at the end of the experiment. Below ground material was separated from soil by soaking each core in water for one hour. These samples were hand washed over a set of three sieves of sizes 1.18mm, and separated into roots and shoot. Samples were oven dried at 60^0C for 72 hour and weighed. The root: shoot ratios was computed for each fodder species as the total below-ground DM over the total accumulated shoot DM (live and dead material).

5.4.5 Parameters measured

Weight of dry matter (Above and below ground biomass), plant height, number of tillers, leaf length, stool diameter, leaf width and leaf numbers as already described in section 3.4.4.

5.4.6 Statistical model

$Y_{ijklm} = \mu + Ri + S_j + I_k + F_l + SI_{jk} + SF_{jl} + IF_{kl} + SIFi_{jkl} + \varepsilon_{ijklm}$

μ - Mean of plot observation,

Ri - Effect of Replication

S_j– Effect of species

I_k – Effect of irrigation interval

F_l – Effect of fertilizer level

SI_{jk}– Interaction between species and irrigation interval

SF_{jl}– Interaction between species and fertilizer level

IF_{kl}– Interaction between irrigation interval and fertilizer level

SIF_{jkl}– Interaction between species and irrigation interval and fertilizer level

ε_{ijklm} – Experimental error

Table 28 Outline of ANOVA for a factorial experiment in RCB design

Source of variation	Degree of freedom	Sum of squares	Mean square	Computed F	Tabular F 5%
Replication (r)	r-1 = 2				
Treatment	IFs_p-1 = 17				
irrigation (i)	i-1 = 2				
Fertilizer (f)	f-1 = 1				
Species (s_p)	s_p-1 = 2				
i x f	(i-1)(f-1) = 2				
i x s_p	(i-1)(s_p-1) = 4				
i x sp	(f-1)(s_p-1) = 2				
i x f x s_p	(i-1)(f-1)(s_p-1) = 4				
Error	(r-1)(ifs_p-1) =				
Total	35				
	$rifs_p$ -1 =				
	50				

5.4.7 Statistical analysis

Statistical analysis was done using the Statistical Analysis System (SAS). Differences among the treatments were tested by analysis of variance (ANOVA) and compared using Standard Error Means (SEM) at the 5% level of significance (Gomez and Gomez, 1984).

Correlation analysis was carried out to determine the association of the treatment effects and the morphological characteristics and biomass yield observed.

5.5 Results and discussions

5.5.1 Relationship between morphological characteristics and treatments

The results of interaction between species, irrigation intervals and fertilizer levels are presented in figures 6, 7 and 8. ANOVA results revealed no significant different ($p \leq 0.05$) observed for the interaction between treatments (Appendix XL). However, significant difference ($p \leq 0.05$) was shown between the species and fertilizer levels and irrigation intervals (main treatment effects) for the following growth characteristics over time: plant height, number of tillers, leaf width and leaf length.

a) Changes in plant height over time for various fodders species

Panicum maximum, Napier *cv Ouma* and *Tripsacum laxum* differed significantly ($p \leq 0.05$) in plant height regardless of fertilzer application and irrigation intervals (Fig. 6a). The plant heights of the forage species increased steadily irrespective of moisture levels and fertilizer applications. This is not surprising since all the plants had just been planted and were still utilizing the parental fertile soil. However, three weeks after of planting, Napier grass *cv Ouma* started to out-compete other species in height throughout the growth period. This result is in agreement with Orodho, (2006) who found Napier grass as a heavier feeder than several other fodder species suggesting that it utilizes more efficiently nutrients absorbed from the soil for growth than alternative grasses. Napier *cv Ouma* and *Tripsacum laxum* peaked about 17 WAP to plant height 91 cm and 75.4 cm respectively while *Panicum maximum* peaked about 14 WAP at plant height 71.1 cm. The growth height responses of the three fodder species were determined by the moisture levels in the soil as well as the available soil nutrients to the growing plants. In addition, different grasses respond differently to water use efficiency and nutrient absorption (Lambers *et al.*, 1998). The Napier *cv Ouma* maintained superior heights over other species followed by *Panicum maximum* and least was *Tripsacum laxum* when fertilizer was added and irrigated at 2-days intervals. The influence of 2-days irrigation interval and fertilization on the height of Napier *cv Ouma* could be explained by better utilization of growth resources by Napier grass *cv Ouma* than *Tripsacum laxum* and *Panicum maximum*. A similar trend was observed in the canopy diameter and tillering ability for Napier *cv Ouma*, which is associated with the manner in which plants absorb and utilize nutrients in the soil.

b) Changes in leaf numbers over time for various fodders species

The leafing ability between *panicum maximum*, Napier *cv Ouma* and *Tripsacum laxum* differed significantly ($p \leq 0.05$) in the fertilizer applied and irrigation intervals received (Figure 6b). The number of leaves per tiller on forage species was steady in the first two weeks after planting but started fluctuating and dropped sharply at the fourteenth week. It however emerged that Napier *cv Ouma* mantained the highest number of leaves throughout the growth period, followed by *Tripsacum laxum* and *Panicum maximum* was the least. This was reflected in the biomass yield as shown in the field experiment (Tables 4 and 5) where Napier grass cv Ouma out-yielded other species.

c) Changes in leaf blade length over time for various fodders species

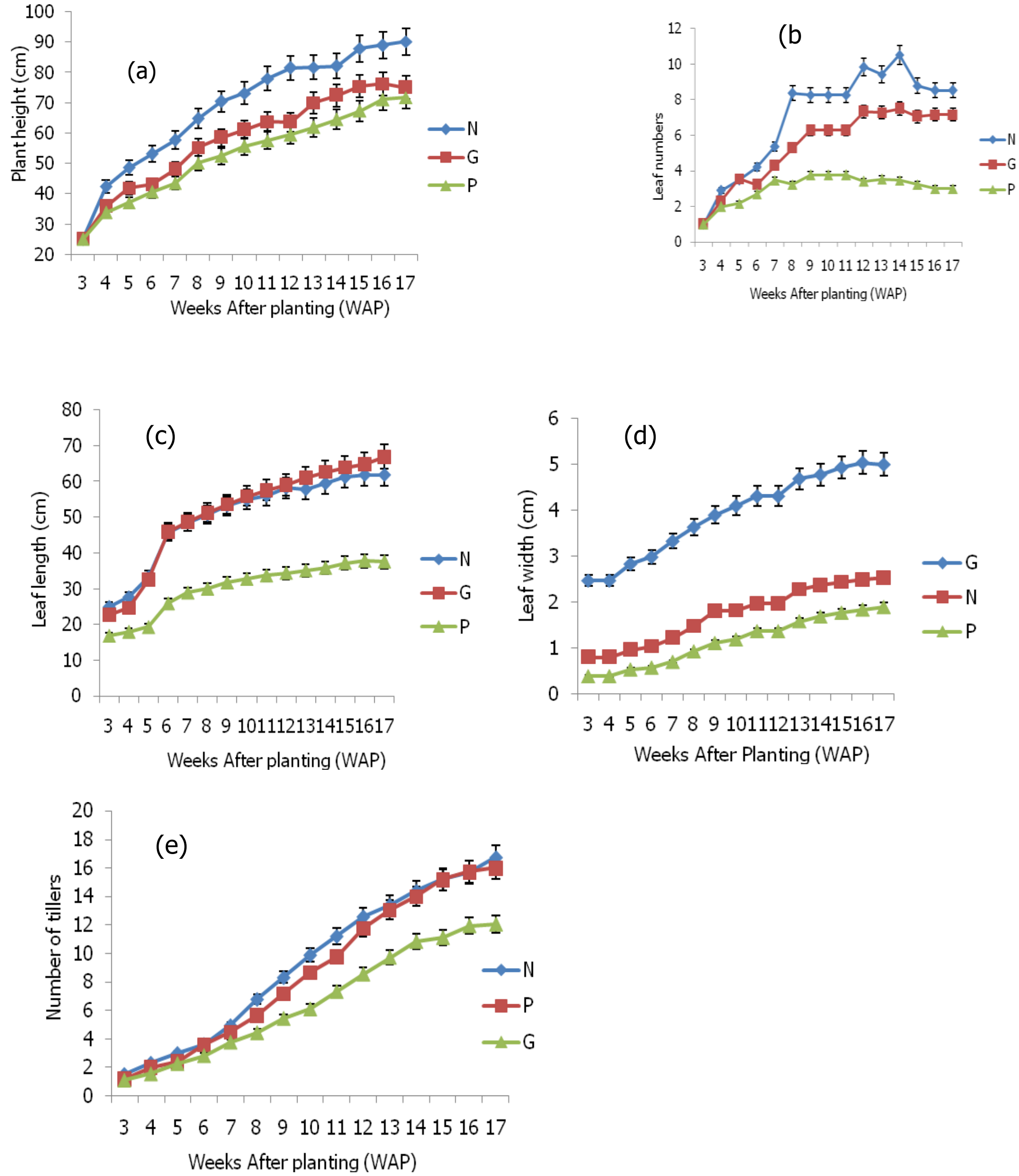
Napier *cv Ouma* and *Tripsacum laxum* were significantly different ($p \leq 0.05$) from the *Panicum maximum* in leaf length (Fig 6c). The length of leaf for Napier *cv Ouma* and *Tripsacum laxum* increased sharply up to 4 WAP to 48 cm. This trend was later mantained up to 15 WAP. *Panicum maximum* had the shortest leaf length throughout the growth period, reaching the peak of 38 cm on the 15 WAP. Naturally morphological leaf length of *Tripsacum laxum* and Napier *cv Ouma* are superior than *Panicum maximum* which was also expressed in the current study.

d) Changes in leaf blade width over time for various fodders species

Tripsacum laxum, Napier grass *cvOuma* and *Panicum maximum* differed significantly in leaf width (Fig. 6d). *Tripsacum laxum* showed significantly the widest leaf width throughout the growth period followed by Napier *cv Ouma* and the shortest was *Panicum mximum*. The leaf width for *Tripsacum laxum* increased steadily from 2.5 cm at week one after planting and peaked at 15 WAP with the width of 4.8 cm. *Panicum maximum* mantained the shortest leaf width throughout the growth period, reaching the peak of 1.8 cm on the 15 WAP.

e) Changes in number of tillers per stool over time for various fodders species

The tillering ability of Napier *cv Ouma* and *Panicum maximum* differed significantly ($p \leq 0.05$) with *Tripsacum laxum* throughout the growing period (Fig 6e). The number of tillers for Napier *cv Ouma* and *Panicum maximum* increased steadily, peaking equally on the 19 WAP to 18 tillers. *Tripsacum laxum* had the lowest number of tillers throughout the growth period, reaching the peak of 12 tillers on the 17 WAP.



Note: N= Napier grass, G= Guatemala grass and P=Panicum
Bars represent the SEM, p≤0.05

Figure 6 Growth trends of forage species in relation to: (a) plant height (b) Leaf numbers (c) Leaf blade length (d) leaf blade width (e) and (e) Number of tillers across moisture regime and fertilizer application.Source:Author 2015

5.5.3 Effect of Irrigation intervals on growth and development of selected alternative grasses to Napier in western Kenya

a) Plant height per tiller

There was significant difference ($P \leq 0.05$) between the irrigation intervals after two days, four days and six days on plant heights (Fig 7a). Irrigation of forage species after two days influenced plant height and peaked at 16 WAP to plant height of 95.8 cm while forage species irrigated at four days interval peaked at 16 WAP and plant height of 78.8cm. Watering at an interval of six days showed the lowest plant heights throughout the experimental period compared to watering at two and four intervals, suggesting that frequent irrigation enabled forage to optimal growth heights. However, infrequent watering similar to 6-days interval contributed to plant wilting and consequently dormancy in growth because the presence of moisture plays important roles in physiological functioning of the plant.

b) Leaf blade length per tiller

Forages irrigated at an interval of two, four and six days significantly differed ($p \leq 0.05$) in leaf length throughout the growth period (Fig 7b). Irrigation after every two and four days showed the longest leaf (7.5 cm) at 10 WAP, followed by a decline due to senescence of some old leaves, which appeared to have been the longest. However, watering after every six days caused stunted growth of leaf length. This could be attributed to the influence of moisture stress on stomata opening and closing in the plant (Taiz and Zeiger, 2002). Thus, during moisture stress, stomata close to conserve water.

This also closes the pathway for exchange of water, carbon-dioxide and oxygen resulting in decrease in photosynthesis, which eventually affect leaf elongation and growth (Taiz and Zeiger, 2002) as shown in this study. Less frequently watered forage experienced the same effect of short leaf length and width which translated into reduced leaf area. This is a modification strategy to avoid evapo-transpiration loss (Anonymous 2010) and increase water use efficiency which helped to tolerate water stress. Low leaf surface area would reduce transpiration rate also by lowering stomata activity (Riaz *et al.* 2008).

c) Leaf numbers per tiller

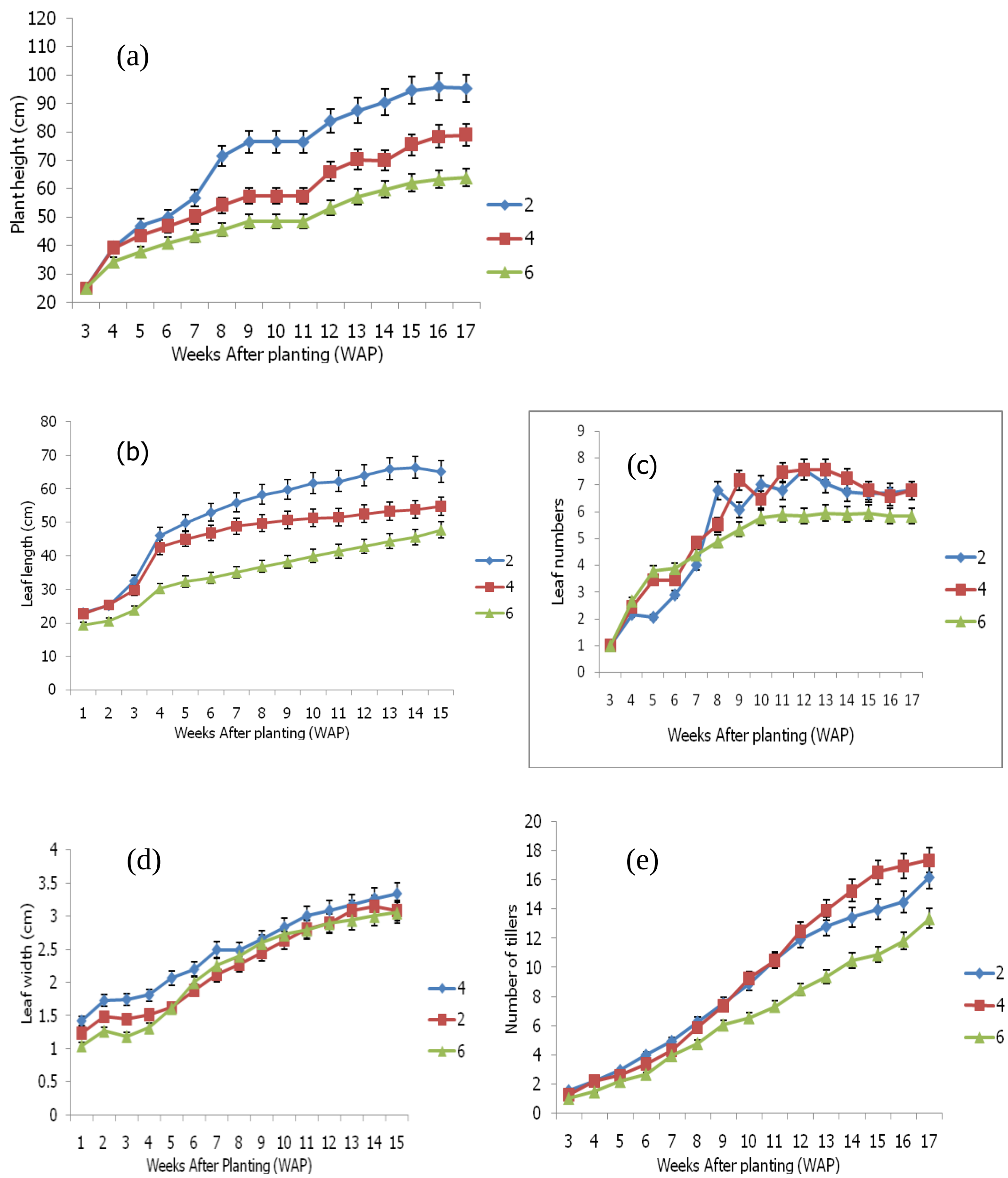
Irrigation of the plants at the interval of two, four and six days showed significant difference ($p \leq 0.05$) in leaf numbers (Fig. 7c). Watering at an interval of two and four days stimulated the formation of more leaves than six days, which peaked at 10 WAP with both levels having seven leaves. However, watering at an interval of six days stimulated the lowest number of leaf formation throughout the growing period, attaining the peak at 10 WAP with six leaves. Number of leaves correlates with biomass production and active growth of the plant. Frequent watering influenced leaf formation which contributed to greater biomass yield.

d) Leaf blade width per tiller

Watering of the plants after every 4 days did not differed significantly ($p \leq 0.05$) with irrigation intervals of 2-days in leaf blade width but differed significantly with 6-days throughout the growth periods (Fig d). Watering after every 2 and 4 days stimulated the widest leaf growth throughout the experimental period regardless of fertilizer application and fodder species. This is in agreement with the findings of Riaz *et al.*, (2008) that water stressed plants similar to the 6-days frequency of watering in the current study reduced the volumes of aerial parts as an adaptation mechanism to survive during water stress period. In addition, they further established that water stressed plants expands their root system to draw water from the depth soils. Forage species under 6-days interval of irrigation showed signs of wilting, folding, and discoloration but regained leaf structure when watered, which re-absorbed water to compensate deficiency experienced over a long period of stress.

e) Number of tillers per stool

There was significant difference between the three irrigation intervals ($P \leq 0.05$) with respect to numbers of tillers (Fig 7f). Plants irrigated at an interval of two and four days influenced formation of more tillers than those irrigated at six days intervals. However, significant difference was observed between irrigation interval of four and two days from the 13 WAP with the 4 weeks irrigation interval out-tillering the two days irrigation interval. Irrigation interval of six days had the lowest number of tillers throughout the growing period attaining the peak at 17 WAP with 13 tillers. Tillering ability is influenced by growth factors such as moisture and fertile soils. Jonassen (1992) found that imposing delaying watering of ryegrass for three weeks had severe effect on tillering.



Note: 2= 2-day irrigation intervals, 4= 4-day irrigation interval and 6= 6-day irigation interval
Bars represent the SEM, p≤0.05

Figure 7: Effect of moisture regimes on growth of: (a) plant height (b) leaf blade length (c) leaf number (d) leaf width (e) and number of tillers across species and fertilizer application.Source:Author 2015

5.5 4 Effect of fertilizer level on growth and development of selected grasses in western Kenya

a) Plant height

Application of fertilizer at the rate of 100kg/ha of DAP increased plant height steadily and were above those which were not fertilized throughout the samplings (Fig 8a). Plant height of forages which were fertilized peaked at 14 WAP, at the height of 82 cm while those not fertilized peaked at 13 WAP at 72 cm height. Similar results were observed by Gasim, (2001) and were associated with input of nitrogen fertilizer which promotes plant growth, increases the number of internodes and length of the internodes which results in progressive increase in plant height. These findings are in full agreement with Akintoye, (1996) that increase plant height with application of fertilizer and is probably due to the increase in leaf length (Figure 8b) under nitrogen treatments, producing more and heavy leaves. However, the increase in plant height for the non-fertilized plants at relatively similar pace could be attributed to the parent soil which was rich in organic compound sourced from the previous land use.

f) Leaf numbers per tiller

The number of leaves per tiller differed significantly ($p \leq 0.05$) between those which received fertilizer and those not fertilized regardless of frequency of irrigation (Fig 8c). Plants which received fertilizer increased leaves steadily above those which were not fertilized throughout the growth period. The fertilized plants peaked at 10 WAP, with 8 leaves while those which were not fertilized peaked at 10 WAP with 7 leaves. After 10 weeks of planting, the number of leaves dropped steadily regardless of fodder species, fertilized and irrigated. While studying the effect of Nitrogen on fodder maize, Amin, (2011) found that increase in the number of leaves per plant could possibly be ascribed to the fact that nitrogen often increases plant growth and plant height. This resulted in more nodes and internodes and subsequently more production of leaves. This explanation could be attributed to the current study since plants which were fertilized were taller and had more leaves.

d) Leaf length per tiller

There was a significant difference ($p \leq 0.05$) between fertilized plants and those not fertilized in leaf length per tiller (Fig 8d). Both treatments increased their leaf length sharply from the first WAP until the fourth WAP with fertilized plants attaining longer leaves than those not fertilized. However, those which increased remained relatively constant until after the fourth WAP, when the fertilized plants attained longer leaf size than those not fertilized. The fertilized plants peaked at 15 WAP, with 62 cm while those not fertilized peaked at 15 WAP with 48 cm. This result may have occurred due to the increase in leaf elongation provided by the greater availability of nitrogen in the soil and tiller height that contributed to the longer leaf blade length (Roma *et al*., 2012, Skinner and Nelson, 1995).

e) Leaf width per tiller

There was a significant difference ($p \leq 0.05$) in leaf width between plants applied with fertilizer at recommended rate and those which were not applied with fertilizer (Fig 8e). Plants applied with fertilizer at the recommended rate of 100kg/ha of DAP increased leaf width steadily above those which were not applied with fertilizer. The fertilized plants peaked at 15 WAP, with 3.3 cm while non-fertilized peaked at 15 WAP with 2.8 cm (Fig 23). The relatively wide width of the non-fertilized plants could be attributed to the rich parental soil which sustained the growth of the plants but at a lower width compared to the fertilized plants.

a) Number of tillers per stool

There was a significant difference ($p \leq 0.05$) between plants applied with fertilizer and those which were not fertilized in tillering ability regardless of frequency of irrigation (Fig 8e). Fertilized fodders increased the number of tillers steadily and were above those which were not applied with fertilizer throughout the sampling period. The fertilized plants peaked at 15 WAP, with 18 tillers while non-fertilized peaked at 15 WAP with 14 tillers. In agreement with the current study, Kizima *et al.*,(2014) reported that application of fertilize significantly affected the appearance of new tillers and increased the dynamics of tiller population of the pasture. These findings are further supported by Mushtaque *et al.*, (2010) who reported that fertilizer application triggers the activation of dormant buds and enhances the vegetation sward filling through the highest rate of tiller replacement, which supports a higher proportion of very active healthier young tillers for each plant. This results in higher tiller density and consequently increases seed and biomass production.

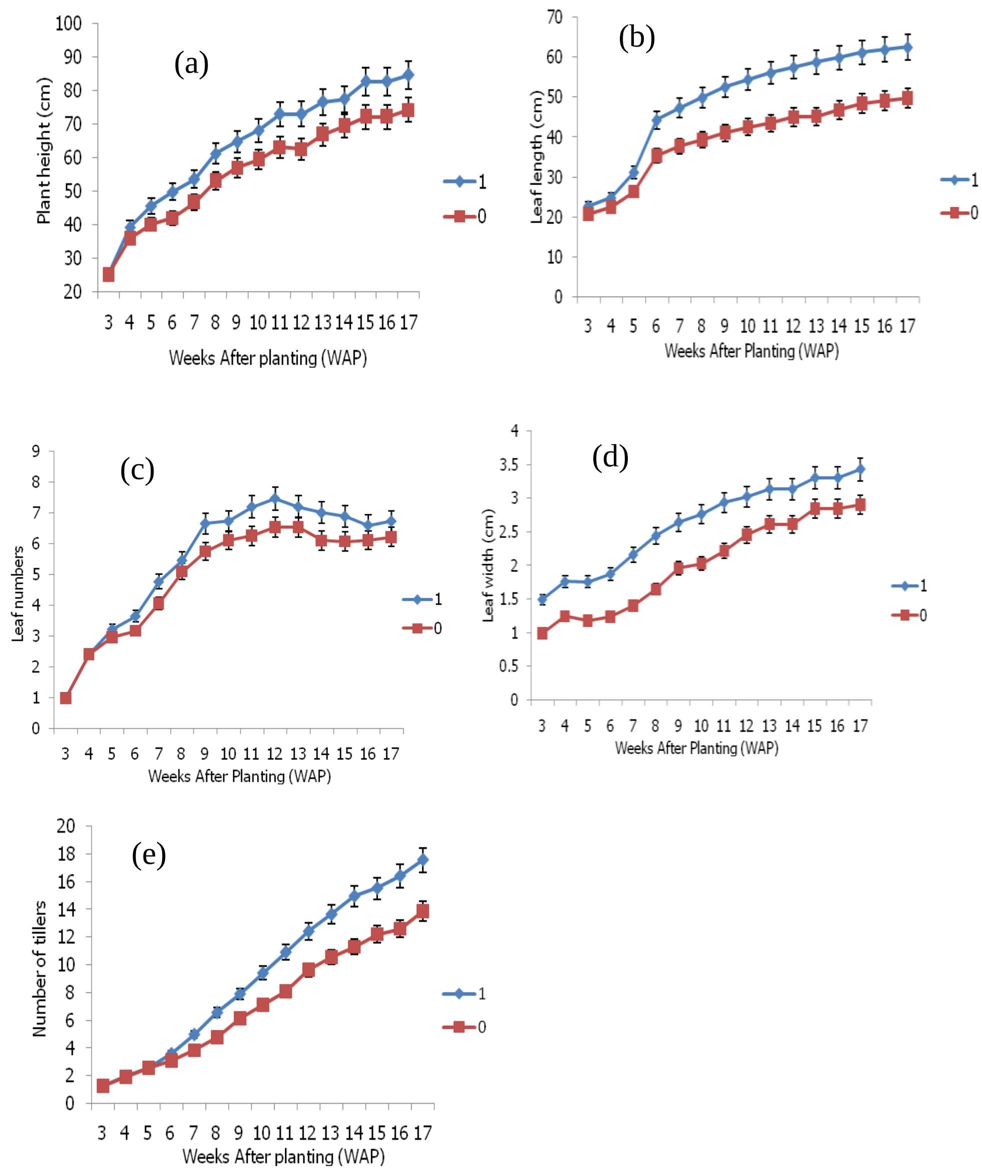


Figure 8: Effect of fertilizer application on: (a) plant height (b) leaf blade length (c) Leaf numbers (d) leaf width (e) numbers of tillers regardless of species and moisture regimes.Source:Author 2015

5.5.5 Correlation matrix for morphological characteristics and biomass yield

There was a significantly correlation between plant height and, root biomass ($r=0.63$, $p\leq0.05$) and shoot biomass ($r=0.64$, $p\leq0.05$). There was also significant correlation ($r=0.60$, $p\leq0.05$) between numbers leaf numbers and leaf length.

The length of leaves was significantly and positively correlated with percentage root dry matter (r=0.84, p≤0.05) and shoot biomass (r=0.76, p≤0.05). This could be associated with increase in leaf formation, stem elongation and tillering ability which increase the biomass production which was also reported by Assuero and Tognettiet, (2010). There was a significant positive correlation (r=0.60, p≤0.05) between the leaf numbers and tillering ability. This may be attributed to the close link between leaf development and tiller formation (Assuero and Tognettiet, (2010). Nascimento Junior, (2002) reported the number of leaves in a tiller as an important reference to the tillering potential because each axillary, can potentially generate a new tiller, and therefore can change the structural characteristics of forage. In their findings, Assuero and Tognettiet, (2010) described tiller production as a function of leaf appearance rate, which may double the appearance of new leaf on the main stem. Napier *cv Ouma* recorded the highest number of leaves which later decline at the peak of 10 leaves due to natural senescence. Few leaves in *Panicum maximum* grass may be attributed to the formation of inflorescence and stem elongation over the synthesis of new leaves as demonstrated by Wentao *et al.*, (2013) and my personal observation during the experimental period.

Table 29 Correlation matrix for mophological characteristics and biomass yield

Plant attributes	Plant height	Leaf numbers	Leaf length	Leaf width	Number of tillers	%DM root	%DM shoot
Plant height		0.26	0.52*	0.21	0.42	0.63*	0.64*
Leaf numbers			0.63*	0.33	0.60*	0.25	0.32
Leaf length				0.60*	-0.17	0.84*	0.76*
Leaf width					-0.40	0.36	0.15
Number of tillers						0.02	0.14
% DM root							0.94*
% DM shoot							

*****Significant at α = 0.05

5.6 Conclusion

1. Fodder species differed significantly in plant growth parameters regardless of interval of irrigation and fertilizer level.
2. Napier *cv Ouma* was taller than *Panicum maximum* and *Guatemala laxum* regardless of interval of irrigation and fertilizer level.
3. Tillering ability for *Panicum maximum was* more than Napier *cv Ouma* and *Guatemala laxum* regardless of interval of irrigation and fertilizer level.
4. There was highest Positive correlation between shoot dry matter and root dry matter followed by leave length and root dry matter and shoots dry matter.

CHAPTER SIX

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6.1 General discussion

The study established that 4-weekly intervals of harvest alongside defoliation heights of 10 cm and 15 cm on Napier cv Ouma out-yielded *Tripsacum laxum* and Panicum at Kakamega and Alupe sites respectively. Among the alternative fodder species, *Panicum maximum* produced highest dry matter yield of 27 t/ha/year and 25.4 t/ha/year at Kakamega and Alupe sites respectively when harvested at 4-weekly intervals alongside defoliation heights of 10cm suggesting that it could be an alternative to Napier grass *cv Ouma* in the absence of tolerant/resistant varieties to Napier stunt disease.

Morphological characteristics of *Tripsacum laxum* showed the largest LAI at both study sites with variations in months of harvest. The highest LAI was influenced by 8-weekly interval of harvest regardless of defoliation height at both study sites. Napier *cv Ouma was* the tallest height when harvested 12-weekly interval regardless of basal height harvested at Kakamega. Among the alternative species, *Panicum maximum* and *Tripsacum laxum* appeared equally tall when harvested at 12-weekly interval regardless of defoliation heights. The tillering ability of Napier *cv Ouma* was more superior than other forages species followed by *Panicum maximum* as an alternative species when harvested at 4- weekly interval alongside basal defoliation height of 5cm. The widest stool diameter was observed on Napier *cv Ouma* when harvested at 8-weekly interval of harvest alongside defoliation basal height of 10cm. Among the alternative fodder species

Panicum maximum harvested at the frequency of 8 weeks regardless of defoliation heights influenced the widest stool diameter growth.

Nutrient analysis of the fodder species revealed that *Tripsacum laxum* contained the highest Crude Protein (CP) levels, though the level of Acid detergent Fibre (ADF) was significantly lower than in Napier *cv Ouma* and *Panicum maximum* regardless of frequency of harvest and defoliation height. A 4-weekly interval of harvest showed higher CP concentration level than other frequencies of harvests regardless species, defoliation heights and plant fractions. The concentration level of CP in leaf was higher than in stem at both sites regardless of the species, frequency of harvest and defoliation heights. Similarly, the leaf factions showed the highest level of Total Digestible Nutrient (TDN) and lowest level of ADF and Neutral detergent Fibre (NDF) regardless of frequency of harvest, defoliation height and species. The concentration level of phosphorus, calcium, potassium and Magnesium in the three fodder species were within the recommended critical level for lactating cows.

The effect of moisture regime and fertilizer level on selected alternative fodder grasses and Napier *cv Ouma* showed significant difference in morphological structures. Napier *cv Ouma* was the tallest and the widest in canopy diameter. *Panicum maximum* had the highest number of tillers followed by Napier *cv Ouma* while *Tripsacum laxum* had the least. Irrigation at intervals of two days performed significantly better than at four and six days. Fertilized fodders performed significantly better than the non-fertilized.

6.2 Conclusions

1. *Panicum maximum* has showed to yield competitively to Napier *cv Ouma* when harvested at 4-weekly interval alongside defoliation height of 10cm and therefore could be an alternative for Napier on the basis of quantity production, while *Tripsacum laxum* is most nutritive alternative forage species regardless of frequency of harvest, defoliation heights and plant fractions.

2. To obtain highest yield cumulatively, livestock keepers should harvest fodder grasses at 4-weekly intervals alongside basal defoliation height of 10 cm and 15 cm regardless of basal defoliation height and plant fraction.

3. The quality of leaf fraction is higher than stem fraction regardless of frequency of harvest, forage species and basal defoliation height and therefore farmers should feed livestock more on forages when are at leafy stage of growth than stemmy.

4. Application of fertilizer and frequent irrigation (2-days and 4 -days interval) improve more on the morphological characteristics of the fodder plant than when fertilizer is not applied and infrequently irrigated (6-days interval).

6.3 Recommendations

1. Based on dry matter yield and nutrient level, farmers should explore possibility of combining *Panicum maximum* and *Tripsacum laxum* as alternative forage for dairy animals.
2. Farmers should harvest fodders at intervals of 4 weeks alongside basal defoliation height of 10 cm in Western Kenya.

3. Where possible, farmers should irrigate fodder grasses at 4-day intervals to increase productivity
4. Farmers should apply DAP at recommended rate to promote growth, development and yield of fodder grasses

6.4 Further research

1. There is need to undertake study on other alternative grasses in order to explore their production potential.
2. There is need to assess nutrient recovery rate after every harvest of the fodder
3. There is need to conduct digestibility study on these forage species with actual dairy animal to determine their influence on performance

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APPENDICES

Appendix I Anova summary showing treatment effect and their interaction on cumulative dry matter yield at Kakamega site

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	2.966585	1.483293	1.47	0.2423
Frequency of defoliation (F)	2	1513.22903	756.61452	2256.37	<.0001
Error A- main plot	4	1.341296	0.335324	0.33	0.8536
Defoliation height (H)	2	764.6488963	382.32445	704.03	<.0001
F*H	4	97.9694074	24.492352	45.1	<.0001
Error B-sub-plot	12	6.516607	0.543051	0.54	0.8736
Species (Sp)	2	2182.238022	1091.119	1084.99	<.0001
F*S	4	71.184348	17.796087	17.7	<.0001
H*S	4	55.846837	13.961709	13.88	<.0001
F*H*S	8	34.181681	4.27271	4.25	**0.0011**
Error C – sub-sub plot	36	36.203378	1.005649		

Appendix II Anova summary showing treatment effect and their interaction on cumulative dry matter yield at Alupe site

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	1.393356	0.696678	1.86	0.1701
Frequency of defoliation (F)	2	1293.504052	646.752026	798.4	<.0001
Error A- main plot	4	3.240237	0.810059	2.16	0.0928
Defoliation height (H)	2	403.9380222	201.9690111	282.76	<.0001
F*H	4	64.0521259	16.0130315	22.42	<.0001
Error B-sub-plot	12	8.571474	0.714290	1.91	0.0667
Species (Sp)	2	2763.522896	1381.76145	3692.52	<.0001
F*S	4	187.333052	46.833263	125.15	<.0001
H*S	4	56.56117	14.140293	37.79	<.0001
F*H*S	8	19.046015	2.380752	6.36	**<.0001**
Error C – sub-sub plot	36	13.471400	0.374206		

Appendix III Anova summary showing treatment effect and their interaction on Leaf Area Index at Kakamega study site in October 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	0.21654321	0.10827160	3.07	0.0587
Frequency of defoliation (F)	2	4.63728395	2.31864198	15.88	0.0125
Error A- main plot	4	0.10716049	0.02679012	0.76	0.5581
Defoliation height (H)	2	0.42691358	0.21345679	6.69	0.0112
F*H	4	0.11234568	0.02808642	0.88	0.5044
Error B-sub-plot	12	0.61407407	0.05117284	1.45	0.1884
Species (Sp)	2	10.70839506	5.35419753	161.82	<.0001
F*S	4	3.50419753	0.87604938	26.48	**<.0001**
H*S	4	0.11012346	0.02753086	0.83	0.5137
F*H*S	8	0.19950617	0.02493827	0.75	0.6446
Error C – sub-sub plot	36	1.26888889	0.03524691		

Appendix IV Anova summary showing treatment effect and their interaction on Leaf Area Index at Kakamega study site in February2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	0.00172840	0.00086420	0.03	0.9742
Frequency of defoliation (F)	2	4.63728395	2.31864198	15.88	0.0125
Error A- main plot	4	0.58419753	0.14604938	4.41	0.0053
Defoliation height (H)	2	0.42691358	0.21345679	6.69	0.0112
F*H	4	0.11234568	0.02808642	0.88	0.5044
Error B-sub-plot	12	0.38296296	0.03191358	0.96	0.4985
Species (Sp)	2	10.70839506	5.35419753	161.82	<.0001
F*S	4	3.50419753	0.87604938	26.48	**<.0001**
H*S	4	0.11012346	0.02753086	0.83	0.5137
F*H*S	8	0.19950617	0.02493827	0.75	0.6446
Error C – sub-sub plot	36	1.19111111	0.03308642		

Appendix V Anova summary showing treatment effect and their interaction on Leaf Area Index at Kakamega study site in June 2013

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	0.46888889	0.23444444	4.68	0.0156
Frequency of defoliation (F)	2	3.54740741	1.7737037	35.39	<.0001
Error A- main plot	4	0.56148148	0.14037037	2.80	0.0402
Defoliation height (H)	2	0.68962963	0.34481481	6.88	0.0029
F*H	4	0.56740741	0.14185185	2.83	0.0387
Error B-sub-plot	12	0.57851852	0.04820988	0.96	0.5009
Species (Sp)	2	6.24888889	3.12444444	62.33	<.0001
F*S	4	3.08148148	0.77037037	15.37	**<.0001**
H*S	4	0.17037037	0.04259259	0.85	0.5032
F*H*S	8	0.70148148	0.08768519	1.75	0.1204
Error C – sub-sub plot	36	1.80444444	0.05012346		

Appendix VI Anova summary showing treatment effect and their interaction on plant height at Kakamega study site in October2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	51.2402	25.6201	0.87	0.4267
Frequency of defoliation (F)	2	102533.4862	51266.7431	1745.08	<.0001
Error A- main plot	4	56.2316	14.0579	0.48	0.7512
Defoliation height (H)	2	72.8699	36.4349	1.24	0.3014
F*H	4	150.02860000	37.5072	1.28	0.2972
Error B-sub-plot	12	743.0793	61.9233	2.11	0.0419
Species (Sp)	2	59624.54900000	59624.549	2029.58	<.0001
F*S	4	36434.33380000	9108.5835	310.05	**<.0001**
H*S	4	146.49230000	36.6231	1.25	0.3088
F*H*S	8	472.52020000	59.065	2.01	0.0732
Error C – sub-sub plot	36	1057.6022	29.3778		

Appendix VII Anova summary showing treatment effect and their interaction on plant height at Kakamega study site in February 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	161.14667	80.57333	0.52	0.5982
Frequency of defoliation (F)	2	60048.00963	30024.00481	185.17	0.0001
Error A- main plot	4	648.58148	162.14537	1.05	0.3957
Defoliation height (H)	2	571.295556	285.647778	1.45	0.2734
F*H	4	1214.619259	303.654815	1.54	0.2529
Error B-sub-plot	12	2367.51407	197.29284	1.28	0.2740
Species (Sp)	2	86226.91556	43113.45778	54.25	<.0001
F*S	4	33542.94815	8385.73704	54.25	**<.0001**
H*S	4	734.24222	183.56056	1.19	0.3329
F*H*S	8	1707.98296	213.49787	1.38	0.2378
Error C – sub-sub plot	36	5564.7644	154.5768		

Appendix VIII Anova summary showing treatment effect and their interaction on plant height at Kakamega study site in June2013

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	70.8719	35.4359	0.49	0.6186
Frequency of defoliation (F)	2	190182.543	95091.2715	359.65	<.0001
Error A- main plot	4	1057.5874	264.3969	3.63	0.0138
Defoliation height (H)	2	135.587407	67.793704	1.25	0.3224
F*H	4	2016.50963	504.127407	9.26	0.0012
Error B-sub-plot	12	653.0363	54.4197	0.75	0.6969
Species (Sp)	2	204591.8341	102295.917	1405.33	<.0001
F*S	4	25254.6496	6313.6624	86.74	<.0001
H*S	4	4586.1889	6313.6624	86.74	<.0001
F*H*S	8	4586.1889	573.2736	7.88	**<.0001**
Error C – sub-sub plot	36	2620.4911	72.7914		

Appendix IX Anova summary showing treatment effect and their interaction on number of tillers at Kakamega study site in October2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	18.298519	9.149259	1.90	0.1648
Frequency of defoliation (F)	2	1053.842222	526.921111	919.35	<.0001
Error A- main plot	4	2.292593	0.573148	0.12	0.9749
Defoliation height (H)	2	40.591852	20.295926	4.09	0.0441
F*H	4	69.663704	17.415926	3.51	0.0405
Error B-sub-plot	12	59.506667	4.958889	1.03	0.4456
Species (Sp)	2	4320.36963	2160.184815	447.74	<.0001
F*S	4	270.863704	2160.184815	14.04	**<.0001**
H*S	4	12.976296	3.244074	0.67	0.6154
F*H*S	8	109.274815	13.659352	2.83	0.0152
Error C – sub-sub plot	36	173.688889	4.824691		

Appendix X Anova summary showing treatment effect and their interaction on number of tillers at Kakamega study site in February 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	121.59877	60.79938	0.83	0.4452
Frequency of defoliation (F)	2	14019.40173	7009.70086	126.17	0.0002
Error A- main plot	4	222.23901	55.55975	0.76	0.5606
Defoliation height (H)	2	321.1980247	160.5990123	1.89	0.1939
F*H	4	127.808642	31.9521605	0.38	0.8219
Error B-sub-plot	12	1021.49778	85.12481	1.16	0.3477
Species (Sp)	2	35021.22765	17510.61383	238.35	<.0001
F*S	4	5472.68568	1368.17142	18.62	**<.0001**
H*S	4	1019.05383	254.76346	3.47	**0.017**
F*H*S	8	993.35506	124.16938	1.69	0.1346
Error C – sub-sub plot	36	2644.77111	73.46586		

Appendix XI Anova summary showing treatment effect and their interaction on number of tillers at Kakamega study site in June2013

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	119.35284	59.67642	0.26	0.7754
Frequency of defoliation (F)	2	13894.74395	6947.37198	173.89	0.0001
Error A- main plot	4	159.81309	39.95327	0.17	0.9516
Defoliation height (H)	2	180.9698765	90.4849383	1.04	0.3818
F*H	4	547.0360494	136.7590123	1.58	0.2428
Error B-sub-plot	12	1039.63407	86.63617	0.37	0.9653
Species (Sp)	2	31777.58691	15888.79346	68.2	<.0001
F*S	4	5842.34123	1460.58531	6.27	**<0.0006**
H*S	4	1567.62864	391.90716	1.68	0.1755
F*H*S	8	2497.60321	312.2004	1.34	0.2558
Error C – sub-sub plot	36	8386.71333	232.96426		

Appendix XII Anova summary showing treatment effect and their interaction on leaf length at Kakamega study site in October 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	130.46247	65.23123	65.23123	0.0521
Frequency of defoliation (F)	2	641.56025	320.7801235	23.28	0.0063
Error A- main plot	4	55.11827	13.77957	0.68	0.6116
Defoliation height (H)	2	554.711358	277.355679	12.42	0.0012
F*H	4	703.8916049	175.9729012	7.88	0.0023
Error B-sub-plot	12	267.87259	22.32272	1.10	0.3906
Species (Sp)	2	19105.60173	9552.80086	470.12	<.0001
F*S	4	604.91235	151.22809	7.44	**0.0002**
H*S	4	9.91012	2.47753	0.12	0.9737
F*H*S	8	198.8758	24.85948	1.22	0.3137
Error C – sub-sub plot	36	731.51333	20.31981		

Appendix XIII Anova summary showing treatment effect and their interaction on leaf length at Kakamega study site in February 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	120.55136	60.27568	1.78	0.1840
Frequency of defoliation (F)	2	111.2306173	55.6153086	1.46	0.3332
Error A- main plot	4	151.89086	37.97272	1.12	0.3631
Defoliation height (H)	2	857.4528395	428.7264198	22.8	<.0001
F*H	4	192.0804938	48.0201235	2.55	0.0934
Error B-sub-plot	12	225.67778	18.80648	0.55	0.8635
Species (Sp)	2	26882.24469	13441.12235	395.83	<.0001
F*S	4	634.55309	158.63827	4.67	**0.0039**
H*S	4	173.81975	43.45494	1.28	0.2961
F*H*S	8	222.56914	27.82114	0.82	0.5908
Error C – sub-sub plot	36	1222.46000	33.95722		

Appendix XIV Anova summary showing treatment effect and their interaction on leaf length at Kakamega study site in June2013

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	308.43556	154.21778	3.57	0.0386
Frequency of defoliation (F)	2	7594.476296	3797.238148	38.2	0.0025
Error A- main plot	4	397.59037	99.39759	2.30	0.0776
Defoliation height (H)	2	189.0318519	94.5159259	2.28	0.1453
F*H	4	426.282963	106.5707407	2.57	0.0924
Error B-sub-plot	12	498.43852	41.53654	0.96	0.5016
Species (Sp)	2	60035.17852	30017.58926	694.48	<.0001
F*S	4	1372.66963	343.16741	7.94	**0.0001**
H*S	4	669.16296	167.29074	3.87	**0.0103**
F*H*S	8	388.54	48.5675	1.12	0.3712
Error C – sub-sub plot	36	1556.04222	43.22340		

Appendix XV Anova summary showing treatment effect and their interaction on stool diameter at Kakamega study site in October 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	2.978025	1.489012	0.66	0.5219
Frequency of defoliation (F)	2	1283.366173	641.683086	224.62	<.0001
Error A- main plot	4	11.427160	2.856790	1.27	0.2995
Defoliation height (H)	2	59.62987654	29.81493827	18.12	0.0002
F*H	4	99.46419753	24.86604938	15.11	0.0001
Error B-sub-plot	12	19.748148	1.645679	0.73	0.7115
Species (Sp)	2	4891.663951	2445.831975	1087.75	<.0001
F*S	4	2603.461235	650.865309	289.46	<.0001
H*S	4	40.401975	10.100494	4.49	0.0048
F*H*S	8	57.859506	7.232438	3.22	**0.0073**
Error C – sub-sub plot	36	80.946667	2.248519		

Appendix XVI Anova summary showing treatment effect and their interaction on stool diameter at Kakamega study site in February 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	29.820988	14.910494	3.72	0.0340
Frequency of defoliation (F)	2	1411.603951	705.801975	292.11	<.0001
Error A- main plot	4	9.664938	2.416235	0.60	0.6629
Defoliation height (H)	2	253.0432099	126.5216049	27.14	<.0001
F*H	4	213.3649383	53.3412346	11.44	0.0005
Error B-sub-plot	12	55.947407	4.662284	1.16	0.3443
Species (Sp)	2	3556.355802	1778.177901	443.8	<.0001
F*S	4	308.53679	77.134198	19.25	**<.0001**
H*S	4	53.98642	13.496605	3.37	**0.0193**
F*H*S	8	33.160988	4.145123	1.03	0.4289
Error C – sub-sub plot	36	144.240000	4.006667		

Appendix XVII Anova summary showing treatment effect and their interaction on stool diameter at Kakamega study site in June 2013

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	25.694074	12.847037	0.71	0.4975
Frequency of defoliation (F)	2	124.8955556	62.4477778	0.79	0.5155
Error A- main plot	4	317.941481	79.485370	4.40	0.0053
Defoliation height (H)	2	165.0288889	82.5144444	9.09	0.004
F*H	4	233.0088889	58.2522222	6.42	0.0053
Error B-sub-plot	12	108.933333	9.077778	0.50	0.8989
Species (Sp)	2	5506.58	2753.29	152.56	<.0001
F*S	4	147.484444	36.871111	2.04	0.109
H*S	4	43.431111	10.857778	0.6	0.6639
F*H*S	8	245.88	30.735	1.7	0.1314
Error C – sub-sub plot	36	649.717778	18.047716		

Appendix XVIII Anova summary showing treatment effect and their interaction on leaf numbers at Kakamega study site- October 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	0.5039506	0.2519753	0.63	0.5360
Frequency of defoliation (F)	2	15.76691358	7.88345679	3.81	0.1186
Error A- main plot	4	8.2827160	2.0706790	5.22	0.0020
Defoliation height (H)	2	0.35728395	0.17864198	1.19	0.3387
F*H	4	0.06271605	0.01567901	0.1	0.9789
Error B-sub-plot	12	1.8066667	0.1505556	0.38	0.9626
Species (Sp)	2	367.0920988	183.5460494	462.29	<.0001
F*S	4	91.465679	22.8664198	0.45	**<.0001**
H*S	4	0.7130864	0.1782716	0.45	0.7724
F*H*S	8	1.0691358	0.133642	0.34	0.34
Error C – sub-sub plot	36	14.2933333	0.3970370		

Appendix XIX Anova summary showing treatment effect and their interaction on leaf numbers at Kakamega study site- February 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	2.2476543	1.1238272	2.19	0.1270
Frequency of defoliation (F)	2	56.04320988	28.02160494	53.72	0.0013
Error A- main plot	4	2.0864198	0.5216049	1.01	0.4127
Defoliation height (H)	2	1.66617284	0.83308642	3.14	0.0803
F*H	4	4.62790123	1.15697531	4.35	0.021
Error B-sub-plot	12	3.1881481	0.2656790	0.52	0.8897
Species (Sp)	2	474.0417284	237.0208642	461.12	<.0001
F*S	4	34.3167901	8.5791975	16.69	**<.0001**
H*S	4	4.1493827	1.0373457	2.02	0.1126
F*H*S	8	5.674321	0.7092901	1.38	0.2383
Error C – sub-sub plot	36	18.5044444	0.5140123		

Appendix XX Anova summary showing treatment effect and their interaction on leaf numbers at Kakamega study site- June2013

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	0.1918519	0.0959259	0.27	0.7639
Frequency of defoliation (F)	2	55.74888889	27.87444444	22.25	0.0068
Error A- main plot	4	5.0103704	1.2525926	3.54	0.0155
Defoliation height (H)	2	1.38740741	0.6937037	1.38	0.288
F*H	4	1.33703704	0.33425926	0.67	0.6273
Error B-sub-plot	12	6.0177778	0.5014815	1.42	0.2026
Species (Sp)	2	785.9940741	392.997037	1111.67	<.0001
F*S	4	73.7037037	18.4259259	52.12	<.0001
H*S	4	7.7140741	1.9285185	5.46	0.0015
F*H*S	8	14.2081481	1.7760185	5.02	**0.0003**
Error C – sub-sub plot	36	12.7266667	0.3535185		

Appendix XXI Anova summary showing treatment effect and their interaction on Leaf Area Index at Alupe study site in October2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	0.03185185	0.01592593	1.32	0.2790
Frequency of defoliation (F)	2	3.78740741	1.8937037	66.4	0.0009
Error A- main plot	4	0.11407407	0.02851852	2.37	0.0708
Defoliation height (H)	2	0.0562963	0.02814815	0.95	0.4126
F*H	4	0.05185185	0.01296296	0.44	0.778
Error B-sub-plot	12	0.35407407	0.02950617	2.45	0.0188
Species (Sp)	2	20.30888889	10.1544444	10.15	<.0001
F*S	4	0.10148148	0.02537037	2.11	0.1
H*S	4	0.17037037	0.04259259	3.54	0.0156
F*H*S	8	0.15925926	0.01990741	1.65	0.1441
Error C – sub-sub plot	36	0.43333333	0.01203704		

Appendix XXII Anova summary showing treatment effect and their interaction on LAI at Alupe study site in February 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	0.09950617	0.04975309	1.72	0.1931
Frequency of defoliation (F)	2	13.63876543	6.81938272	57.84	0.0011
Error A- main plot	4	0.47160494	0.11790123	4.08	0.0079
Defoliation height (H)	2	0.85802469	0.42901235	21.25	0.0001
F*H	4	0.04864198	0.01216049	0.6	0.6682
Error B-sub-plot	12	0.24222222	0.02018519	0.70	0.7420
Species (Sp)	2	10.6854321	5.34271605	184.94	<.0001
F*S	4	0.78790123	0.19697531	6.82	**0.0003**
H*S	4	0.27753086	0.06938272	2.4	0.0678
F*H*S	8	0.27580247	0.03447531	1.19	0.3302
Error C – sub-sub plot	36	1.04000000	0.02888889		

Appendix XXIII Anova summary showing treatment effect and their interaction on Leaf Area Index at Alupe study site in June 2013

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	0.08469136	0.04234568	1.28	0.2917
Frequency of defoliation (F)	2	0.1380247	0.06901235	1.65	0.3
Error A- main plot	4	0.16716049	0.04179012	1.26	0.3042
Defoliation height (H)	2	0.7424691	0.37123457	11.54	0.0016
F*H	4	0.2538272	0.06345679	1.97	0.1629
Error B-sub-plot	12	0.38592593	0.03216049	0.97	0.4952
Species (Sp)	2	4.15284	2.07641975	62.52	<.0001
F*S	4	4.1879012	1.04697531	31.53	<.0001
H*S	4	0.1412346	0.03530864	1.06	0.3888
F*H*S	8	0.8224691	0.10280864	3.1	**0.0092**
Error C – sub-sub plot	36	1.19555556	0.03320988		

Appendix XXIV Anova summary showing treatment effect and their interaction on plant height at Alupe study site in October2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	59.13185	29.56593	1.65	0.2060
Frequency of defoliation (F)	2	37761.02296	18880.51148	1790.72	<.0001
Error A- main plot	4	42.17407	10.54352	0.59	0.6728
Defoliation height (H)	2	126.9540741	63.477037	3.61	0.0594
F*H	4	222.342963	55.5857407	3.16	0.0545
Error B-sub-plot	12	211.26963	17.60580	0.98	0.4825
Species (Sp)	2	29275.22	14637.61	817.57	<.0001
F*S	4	2010.09481	502.5237	28.07	**<.0001**
H*S	4	104.82815	26.20704	1.46	0.2335
F*H*S	8	100.78593	12.59824	0.7	0.6862
Error C – sub-sub plot	36	644.53778	17.90383		

Appendix XXV Anova summary showing treatment effect and their interaction on plant height at Alupe study site in February 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	95.22000	47.61000	1.98	0.1534
Frequency of defoliation (F)	2	76303.44296	38151.72148	1266.27	<.0001
Error A- main plot	4	120.51704	30.12926	1.25	0.3074
Defoliation height (H)	2	62.7562963	31.3781481	1.75	0.2148
F*H	4	165.6785185	41.4196296	2.31	0.1169
Error B-sub-plot	12	214.74519	17.89543	0.74	0.7015
Species (sp)	2	84601.78667	42300.89333	1755.44	<.0001
F*S	4	55898.27259	13974.56815	579.93	**<.0001**
H*S	4	170.76593	42.69148	1.77	0.156
F*H*S	8	308.2637	38.53296	1.6	0.1596
Error C – sub-sub plot	36	867.4911	24.0970		

Appendix XXVI Anova summary showing treatment effect and their interaction on plant height at Alupe study site in June 2013

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	280.2862	140.1431	2.58	0.0900
Frequency of defoliation (F)	2	88842.5047	44421.25235	816.49	<.0001
Error A- main plot	4	408.2812	102.0703	1.88	0.1359
Defoliation height (H)	2	1983.727654	991.863827	18.23	<.0001
F*H	4	769.584198	192.396049	3.54	0.0156
Error B-sub-plot	12	1338.3170	111.5264	2.05	0.0480
Species (Sp)	2	163939.8773	81969.9386	1506.66	<.0001
F*S	4	13690.3012	3422.5753	62.91	<.0001
H*S	4	2157.0138	539.2535	9.91	<.0001
F*H*S	8	1689.5588	211.1948	3.88	**0.0022**
Error C – sub-sub plot	36	1958.5889	54.4052		

Appendix XXVII Anova summary showing treatment effect and their interaction on number of tillers at Alupe study site in October 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	4.373580	2.186790	0.80	0.4561
Frequency of defoliation (F)	2	19.49358025	9.74679012	0.96	0.4573
Error A- main plot	4	4.373580	2.186790	0.80	0.4561
Defoliation height (H)	2	8.33802469	4.16901235	2.22	0.1507
F*H	4	11.1982716	2.7995679	1.49	0.265
Error B-sub-plot	12	22.485926	1.873827	0.69	0.7520
Species (Sp)	2	4444.366173	2222.183086	815.46	<.0001
F*S	4	207.505679	51.87642	19.04	**<.0001**
H*S	4	5.561235	1.390309	0.51	0.7286
F*H*S	8	38.204691	4.775586	1.75	0.1197
Error C – sub-sub plot	36	98.102222	2.725062		

Appendix XXVIII Anova summary showing treatment effect and their interaction on number of tillers at Alupe study site in February

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	7.90741	3.95370	1.16	0.3245
Frequency of defoliation (F)	2	24109.479	12054.739	3765.58	<.0001
Error A- main plot	4	12.80519	3.20130	0.94	0.4518
Defoliation height (H)	2	327.43407	163.71704	37.04	<.0001
F*H	4	120.96296	30.240741	6.84	0.0041
Error B-sub-plot	12	53.04074	4.42006	1.30	0.2618
Species (Sp)	2	28835.4	14417.7	4234.96	<.0001
F*S	4	18387.563	4596.8907	1350.26	<.0001
H*S	4	311.22296	77.80574	22.85	<.0001
F*H*S	8	498.50889	62.31361	18.3	**<.0001**
Error C – sub-sub plot	36	122.56000	3.40444		

Appendix XXIX Anova summary showing treatment effect and their interaction on number of tillers at Alupe study site in June 2013

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	306.32519	153.16259	5.04	0.0118
Frequency of defoliation (F)	2	14489.11407	7244.55704	76.9	0.0006
Error A- main plot	4	376.85185	94.21296	3.10	0.0273
Defoliation height (H)	2	101.0718519	50.5359259	3.02	0.0866
F*H	4	780.2340741	195.0585185	11.66	0.0004
Error B-sub-plot	12	200.76963	16.73080	0.55	0.8662
Species (Sp)	2	30196.96222	15098.48111	496.53	<.0001
F*S	4	13843.0837	3460.77093	113.81	**<.0001**
H*S	4	528.48815	47.96981	1.58	0.2013
F*H*S	8	528.48815	66.06102	2.17	0.0536
Error C – sub-sub plot	36	1094.68000	30.40778		

Appendix XXX Anova summary showing treatment effect and their interaction on leaf lengths at Alupe study site in October2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	196.55407	98.27704	3.55	0.0393
Frequency of defoliation (F)	2	2182.494074	1091.247037	64.1	0.0009
Error A- main plot	4	68.09407	17.02352	0.61	0.6551
Defoliation height (H)	2	451.2822222	225.6411111	3.51	0.0629
F*H	4	233.7614815	58.4403704	0.91	0.4888
Error B-sub-plot	12	770.50963	64.20914	2.32	0.0257
Species (Sp)	2	36558.06889	18279.03444	659.68	<.0001
F*S	4	2646.85037	661.71259	23.88	**<.0001**
H*S	4	208.74741	13.56944	0.49	0.7432
F*H*S	8	208.74741	26.09343	0.94	0.4953
Error C – sub-sub plot	36	997.52889	27.70914		

Appendix XXXI Anova summary showing treatment effect and their interaction on leaf length at Alupe study site in February 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	2.73802	1.36901	0.03	0.9693
Frequency of defoliation (F)	2	110.32395	55.161975	1.92	0.2607
Error A- main plot	4	115.10420	28.77605	0.66	0.6261
Defoliation height (H)	2	531.97506	265.98753	8.62	0.0048
F*H	4	552.78716	138.19679	4.48	0.0191
Error B-sub-plot	12	370.21556	30.85130	0.70	0.7372
Species (Sp)	2	39766.68	19883.34	453.68	<.0001
F*S	4	2149.2746	537.31864	12.26	**<.0001**
H*S	4	193.69679	48.4242	1.1	0.3692
F*H*S	8	618.04099	77.25512	1.76	0.1174
Error C – sub-sub plot	36	1577.76889	43.82691		

Appendix XXXII Anova summary showing treatment effect and their interaction on leaf length at Alupe study site in June 2013

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	229.70074	114.85037	3.31	0.0480
Frequency of defoliation (F)	2	6782.147407	3391.073704	60.9	0.001
Error A- main plot	4	222.71852	55.67963	1.60	0.1946
Defoliation height (H)	2	324.8051852	162.4025926	9.89	0.0029
F*H	4	567.2651852	141.8162963	8.64	0.0016
Error B-sub-plot	12	197.05185	16.42099	0.47	0.9175
Species (Sp)	2	43923.57407	21961.78704	632.37	<.0001
F*S	4	2763.8163	690.95407	19.9	**<.0001**
H*S	4	37.74963	9.43741	0.27	0.8942
F*H*S	8	150.77778	18.84722	0.54	0.8164
Error C – sub-sub plot	36	1250.26222	34.72951		

Appendix XXXIII Anova summary showing treatment effect and their interaction on stool diameter at Alupe study site in October 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	0.069877	0.034938	0.01	0.9927
Frequency of defoliation (F)	2	686.8758025	343.4379012	51.03	0.0014
Error A- main plot	4	26.918272	6.729568	1.42	0.2472
Defoliation height (H)	2	34.1402469	17.0701235	3.88	0.0502
F*H	4	150.1790123	37.5447531	8.53	0.0017
Error B-sub-plot	12	52.818519	4.401543	0.93	0.5299
Species (Sp)	2	1658.05358	829.02679	174.91	<.0001
F*S	4	96.459012	24.114753	5.09	**0.0024**
H*S	4	10.354568	2.588642	0.55	0.7029
F*H*S	8	12.979506	1.622438	0.34	0.9432
Error C – sub-sub plot	36	170.633333	4.739815		

Appendix XXXIV Anova summary showing treatment effect and their interaction on stool diameter at Alupe study site in February 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	5.122963	2.561481	0.42	0.6610
Frequency of defoliation (F)	2	1994.5919	997.295926	968.07	<.0001
Error A- main plot	4	4.120741	1.030185	0.17	0.9531
Defoliation height (H)	2	52.305185	26.1525926	7.45	0.0079
F*H	4	216.07407	54.0185185	15.39	0.0001
Error B-sub-plot	12	42.120741	3.510062	0.57	0.8483
Species (Sp)	2	1873.734	936.867037	153.19	<.0001
F*S	4	126.89185	31.722963	5.19	**0.0021**
H*S	4	5.260741	1.315185	0.22	0.9284
F*H*S	8	83.171111	10.396389	1.7	0.1322
Error C – sub-sub plot	36	220.168889	6.115802		

Appendix XXXV Anova summary showing treatment effect and their interaction on stool diameter at Alupe study site in June 2013

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	3.366173	1.683086	0.22	0.8074
Frequency of defoliation (F)	2	295.511358	147.755679	21.19	0.0074
Error A- main plot	4	27.887901	6.971975	0.89	0.4790
Defoliation height (H)	2	38.1817284	19.0908642	6.55	0.012
F*H	4	400.8679012	100.2169753	34.36	<.0001
Error B-sub-plot	12	34.999259	2.916605	0.37	0.9649
Species (Sp)	2	3846.419506	1923.209753	245.92	<.0001
F*S	4	202.154568	50.538642	50.538642	0.0005
H*S	4	82.141975	20.535494	2.63	0.0505
F*H*S	8	143.150617	17.893827	2.29	**0.0429**
Error C – sub-sub plot	36	281.533333	7.820370		

Appendix XXXVI Anova summary showing treatment affects on leaf numbers at Alupe study site in October 2013

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	5.9207407	2.9603704	6.14	0.0051
Frequency of defoliation (F)	2	45.12296296	22.56148148	39	0.0024
Error A- main plot	4	2.3140741	0.5785185	1.20	0.3276
Defoliation height (H)	2	0.48222222	0.24111111	0.34	0.7215
F*H	4	4.08592593	1.02148148	1.42	0.2858
Error B-sub-plot	12	8.6229630	0.7185802	1.49	0.1731
Species (Sp)	2	697.0340741	348.517037	722.92	<.0001
F*S	4	24.4118519	6.102963	12.66	**<.0001**
H*S	4	1.5459259	0.3864815	0.8	0.5322
F*H*S	8	5.6059259	0.7007407	1.45	0.2087
Error C – sub-sub plot	36	17.3555556	0.4820988		

Appendix XXXVII Anova summary showing treatment affects on leaf numbers at Alupe study site in February 2012

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	0.8254321	0.4127160	0.55	0.5820
Frequency of defoliation (F)	2	12.803951	6.40197531	1.84	0.2711
Error A- main plot	4	13.9071605	3.4767901	4.63	0.0041
Defoliation height (H)	2	0.3750617	0.18753086	0.22	0.808
F*H	4	3.9930864	0.9982716	1.15	0.378
Error B-sub-plot	12	10.3718519	0.8643210	1.15	0.3532
Species (Sp)	2	66.68568	386.74679	514.86	<.0001
F*S	4	66.685679	16.6714198	22.19	**<.0001**
H*S	4	1.0834568	0.2708642	0.36	0.835
F*H*S	8	6.8350617	0.8543827	1.14	0.3628
Error C – sub-sub plot	36	27.0422222	0.7511728		

Appendix XXXVIII Anova summary showing treatment affects on leaf numbers at Alupe study site in June 2013

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Block	2	1.0091358	0.5045679	0.79	0.4614
Frequency of defoliation (F)	2	40.81283951	20.40641975	49.18	0.0015
Error A- main plot	4	1.6597531	0.4149383	0.65	0.6306
Defoliation height (H)	2	0.47506173	0.23753086	0.3	0.7431
F*H	4	3.34938272	0.83734568	1.07	0.412
Error B-sub-plot	12	9.3622222	0.7801852	1.22	0.3063
Species (Sp)	2	664.1602469	332.0801235	520.18	<.0001
F*S	4	32.7641975	8.1910494	12.83	**<.0001**
H*S	4	3.5730864	0.8932716	1.4	0.2539
F*H*S	8	9.6135802	1.2016975	1.88	0.0935
Error C – sub-sub plot	36	22.9822222	0.6383951		

Appendix XXXIX Anova summary showing treatment effect and their interaction on crude protein levels in plants

Source of variation	DF	Anova SS	Mean Square	F Value	Pr > F
Species (Sp)	2	95.62	47.81	6.43	**0.004**
Frequency of defoliation (F)	2	283.55	141.78	19.06	**<.0001**
Sp *F	4	47.81	11.95	1.61	0.19
Height (h)	2	26.62	13.31	1.79	0.18
Sp*H	4	25.49	6.37	0.86	0.50
F*H	4	0.16	0.04	0.01	1.00
Sp*F*H	8	96.04	12.00	1.61	0.15
Portion (P)	2	974.50	487.25	65.52	**<.0001**
Sp*P	4	32.86	8.22	1.10	0.3673
F*P	3	0.00	0.00	0.00	1.00
H*P	4	2.19	0.55	0.07	0.9898
Sp*F*P	3	0	0	0	1.000
Sp*H*p	8	14.27	1.78	0.24	0.9807

Appendix XL Anova summary showing treatment effect and their interaction on growth and development of selected grasses.

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Replicate (R)	2	2200.11091	1100.05545	2.45	0.1018
Species (Sp)	2	12790.51000	6395.25500	14.22	**<.0001**
Irrigation interval (I)	2	31403.26704	15701.63352	34.90	**<.0001**
Fertilizer (F)	1	57011.26483	57011.26483	126.73	**<.0001**
I*Sp	4	4175.22852	1043.80713	2.32	0.0767
Sp*F	2	2020.33531	1010.16765	2.25	0.1213
I*F	2	1317.97938	658.98969	1.46	0.2453
I*Sp*F	4	928.68840	232.17210	0.52	0.7244
Error	34	15295.03298	449.85391		